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Ku-Band High Power Amplifier
System Functionality and Operation

by

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June 1990

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The subsystems and their respective functionality of a ku-band high power amplifier are carefully documented. Figures identifying physical components, wiring, contact points, switches, and valves with their labels on the system blueprints are presented. These figures will be helpful if system performance parameter adjustments are desired. Operation, maintenance, troubleshooting and testing procedures are also included to make this thesis a self-contained operator's manual for the high power amplifier.

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ABSTRACT

The subsystems and their respective functionality of a ku-band high power amplifier are carefully documented. Figures identifying physical components, wiring, contact points, switches and valves with their labels on the system blueprints are presented. These figures will be helpful if system performance parameter adjustments are desired. Operation, maintenance, troubleshooting and testing procedures are also included to make this thesis a self-contained operator's manual for the high power amplifier.

TABLE OF CONTENTS

I. INTRODUCTION

The High Power Amplifier (HPA) studied in this thesis was built by Ground System Group of Hughes Aircraft Company for the Naval Research Laboratory (NRL) in 1980. In November 1982, a new Solid State Modulator (SSM) was installed to improve system reliability and performance. A total of four units with SSM were built. One of them was transferred to the Naval Postgraduate School (NPS) in August 1989 for research in radar signal propagation and scattering.

The heart of the HPA is a high power traveling wave tube (TWT). It amplifies and modulates a one watt signal into a 10 kilowatt pulse of up to ten microseconds width. To achieve such power amplification, a direct current (DC) voltage drop as high as 30 kilovolts has to be present between the anode and the cathode of the tube. To supply the free electron flow in the tube, an ion pump is needed. To confine the high energy electrons, a solenoid is required to set up a magnetic field in the TWT. Pulse modulation is accomplished through turning on and off the flow of electrons in the TWT via applying a positive or a negative bias to the grid.

Working with such a high power, high voltage system calls for carefully implemented safety features. Many monitoring and interlocking mechanisms are built into the HPA. As complicated as such a system may be, all the available information on the operation, maintenance and performance of the system is limited to several blueprints and two technical reports, one entitled *Technical Manual For Special Purpose Transmitter* [Ref. 1]; the other on the performance testing of the *SSM*

[Ref. 2]. Hence when the HPA arrived at the Microwave Propagation Lab with severed wires with labels not matching any description in the *Technical Manual*, it become the first priority to look into the blueprints and to physically identify on the HPA each item described in the *Technical Manual.*

This goal is achieved in chapter II of this thesis. Not considering the flow charts, the figures in chapter II are grouped according to the functionality of the HPA subsystems. All these figures are in fact overlays of the relevant parts of the blueprints on the physical HPA. Related work performed on the HPA but not included in this thesis is the identification and labeling of the HPA subsystems, components, wires, connectors, junctions, switches and valves in accordance with their labels on the blueprints.

Chapter III describes the facility requirements and the operation, maintenance and troubleshooting procedures of the HPA. Only those requirements and procedures most directly related to setting up and operating the HPA at NPS are included in this chapter. The rest are placed in the Appendices. Appendix A contains flow charts of the maintenance procedures adapted from the *Technical Manual.* Appendix B contains flow charts which combine step-by-step instructions of the *Technical Manual* with explanatory notes for troubleshooting.

Appendix C lists the specifications of the TWT which are either scattered throughout the *Technical Manual* or found only on the label attached to the TWT. For easy reference, the many abbreviations and labels related to the HPA are listed in Appendix D.

This thesis will serve as the HPA manual specifically written for the unit in the Microwave Propagation Lab.

II. HIGH POWER AMPLIFIER SYSTEM CIRCUITRY AND FUNCTIONALITY

This High Power Amplifier (HPA) is a ku-band high power amplifier, with an average power of 3.4 kW and a peak power of 10 kW. It uses a Traveling Wave Tube (TWT) for amplification of the RF signal. The system configuration is shown in Figure 1.

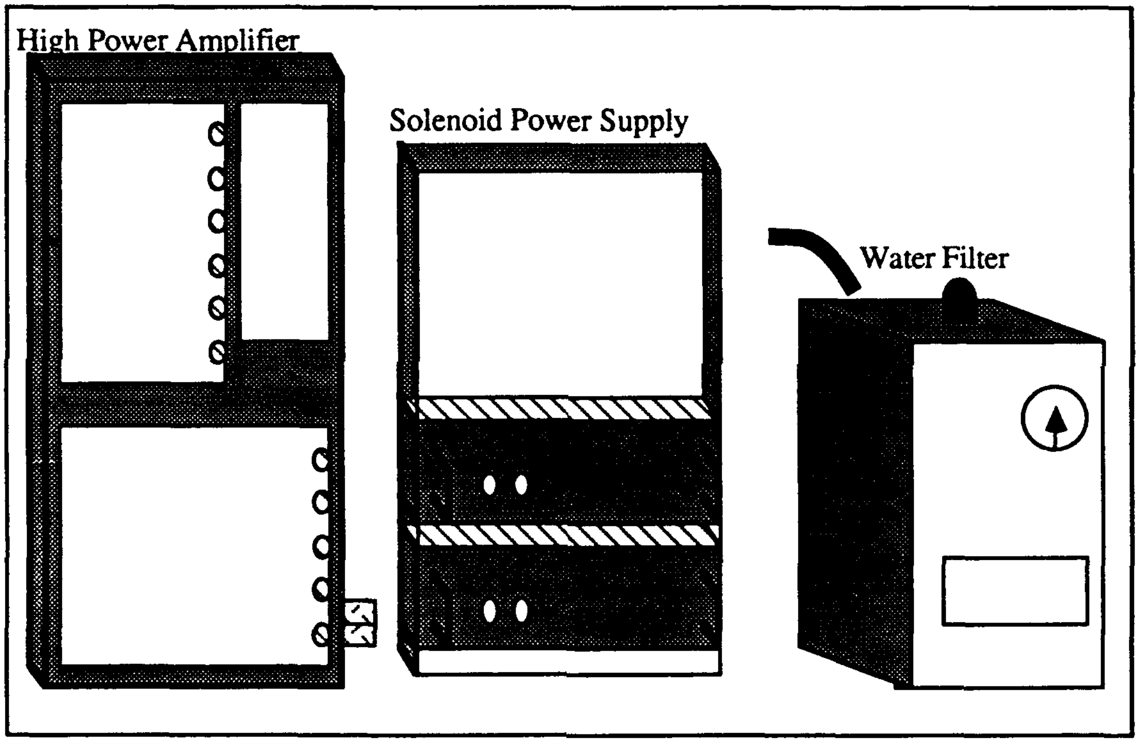

Figure 1 HPA Physical setup

The HPA system physically separates into the HPA cabinet, the Solenoid Power Supply cabinet and the Water Filter. They are currently located in room Sp-537.

According to their functions, the HPA can be separated into the following six functional units as shown in Figure 2.

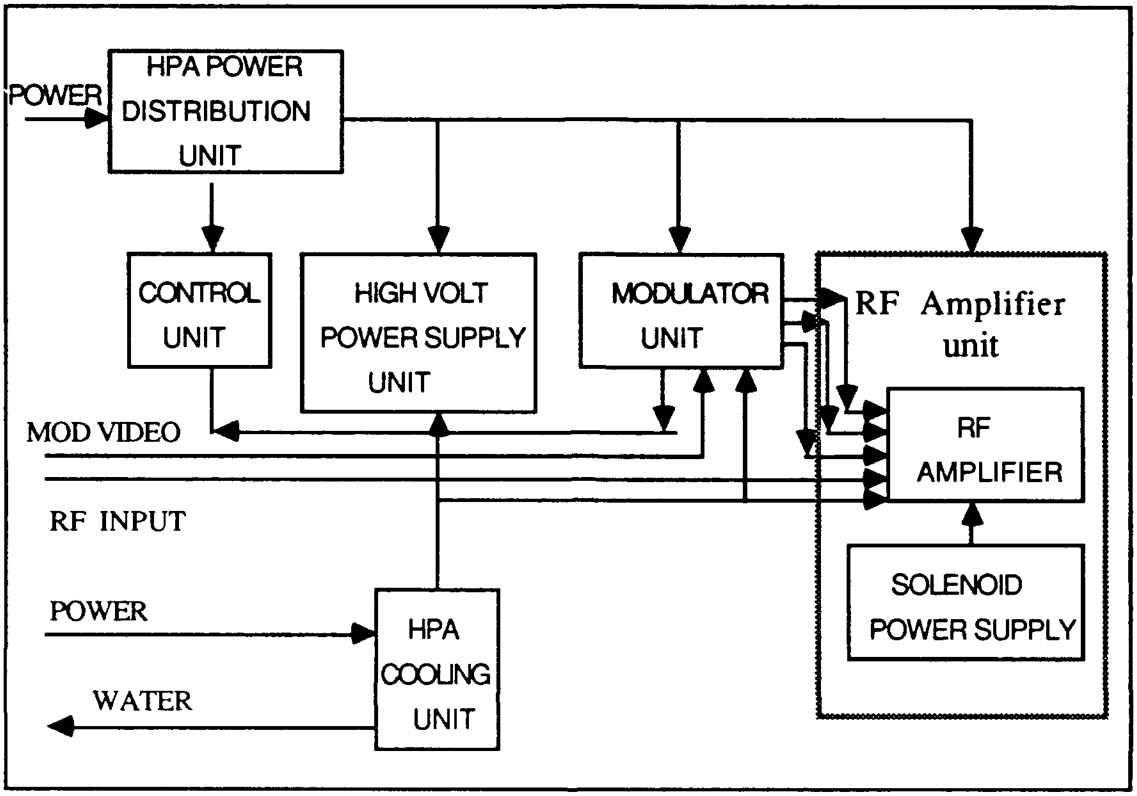

Figure 2 HPA Functional Blocks

1. RF Amplifier Unit.
2. High Voltage Power Supply Unit.
3. Modulator Unit.
4. Control Unit.
5. HPA Power Distribution Unit.
6. HPA Cooling Unit.

The following sections describe the functions and the circuitry of each unit. The abbreviations of the components will be introduced in parentheses and used in the schematic drawings and block diagrams.

A. RF AMPLIFIER UNIT

The purpose of this unit is to provide RF amplification and to monitor the RF incoming and outgoing signals to prevent damages to the TWT caused by reflected RF power. The unit consists of a high power TWT, an ion pump power supply, monitoring circuits, and a solenoid power supply. All these circuits are housed in the HPA cabinet, except the solenoid power supply which is housed in a separate cabinet. The block diagram of this unit is shown in Figure 3.

1. RF Amplifier

This component contains the primary parts of the RF amplifier unit. These parts include all the elements the RF signal pass through.

a. The Directional Couplers (DC1, DC2)

The direction couplers DC1 and DC2 couple RF signal out of the waveguide for testing. They are located respectively at the beginning and at the end of the waveguide inside the HPA. DC2 also routes samples of reflected RF signals through the 25 dB attenuator (AT2) and a power detector to the monitor circuit (A9) to detect the presence of high VSWR.

b. The Liquid-cooled Circulators (AT1, AT8)

The circulator (AT8) attenuates reflected RF and isolates the high power TWT from the load during waveguide arcs or high VSWR

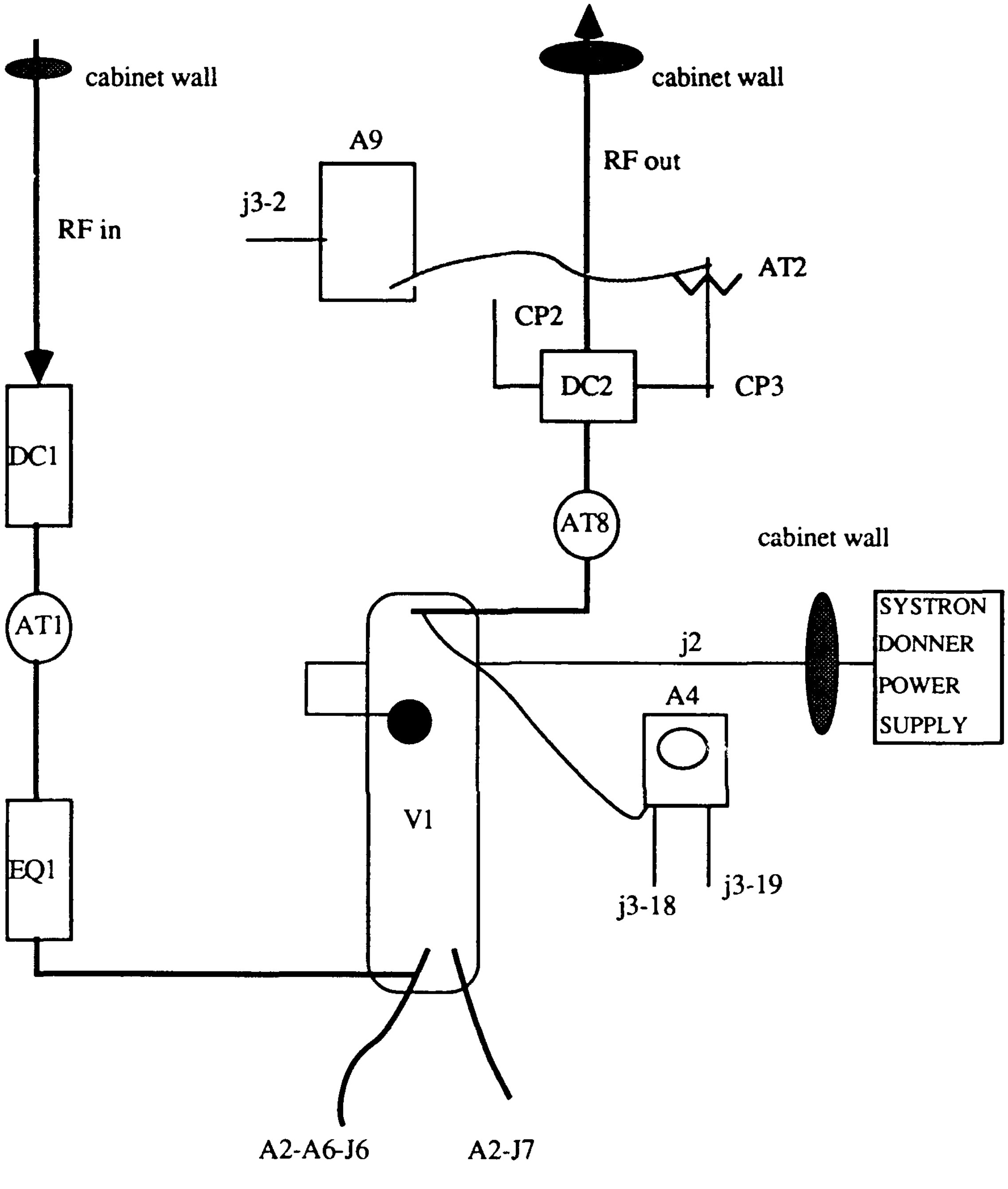

Figure 3 RF Amplifier Unit Block Diagram

situations. The AT8 is located above the TWT. It minimizes the effect of load impedance mismatch to the high power TWT.

The circulator (AT1) prevents any leakage from the TWT to backup into the low power RF driver. It is located under CD1.

c. The Equalizer (EQ1)

The equalizer (EQ1) matches the input impedance of the high power TWT to the waveguide and is located under AT1.

d. TWT (V1)

The TWT (V1) provides the final amplification of the RF signal. The TWT specifications are given in Appendix C.

2. Ion Pump Power Supply (A4)

The ion pump power supply furnishes an approximately +3.8 kV voltage to the TWT ion pump. It is located next to the TWT. The ion pump, located inside the TWT, is part of the TWT. It continuously ionizes the gas inside the TWT to free up electrons for RF amplification.

3. Solenoid Power Supply

Two Systron Donner Power Supplies are connected in series to provide the solenoid of the RF amplifier with a power of 320 V at 15 amperes maximum.

4. Cathode-to-Body Voltage Cable (A2A6j6)

The wire A2A6j6 is the high voltage cable used by the high voltage power supply unit to provide the -28 to -34 kV voltage to the TWT cathode.

5. Collector-to-Body Voltage Cable (A2j7)

The high voltage power supply unit provides the -8.9 to -10.8 kV voltage to the TWT collector through the high voltage cable A2j7.

B. HIGH VOLTAGE POWER SUPPLY UNIT

The high voltage power supply unit provides the cathode-to-body and the collector-to-body voltages to the TWT. The unit consists of an error amplifier/inverter driver card, an inverter assembly, and high voltage power supplies for the cathode and for the collector. Assemblies containing the high voltage circuits, inverter and the high voltage power supplies are immersed in a Fluorinert compound, FC77, inside the high voltage assembly. The fluid serves the dual purpose of cooling the components and providing high voltage insulation. The error amplifier/inverter driver card is located outside on top of the high voltage assembly. The unit is shown schematically in Figure 4.

1. Rectifier Filter Assembly (A5)

The rectifier filter assembly provides dc power to the inverter assembly. The assembly rectifies and filters the 440 V 400 Hz 3-phase prime power with the use of a choke input filter. A power factor close to one is achieved while supplying a nominal output voltage of 600 Vdc.

2. Error Amplifier and Inverter Driver Card (A2j1)

The error amplifier and inverter driver card senses the high voltage and indirectly regulates the high voltage power supply output by sending the silicon-controlled-rectifier (SCR) drive pulses to the inverter assembly.

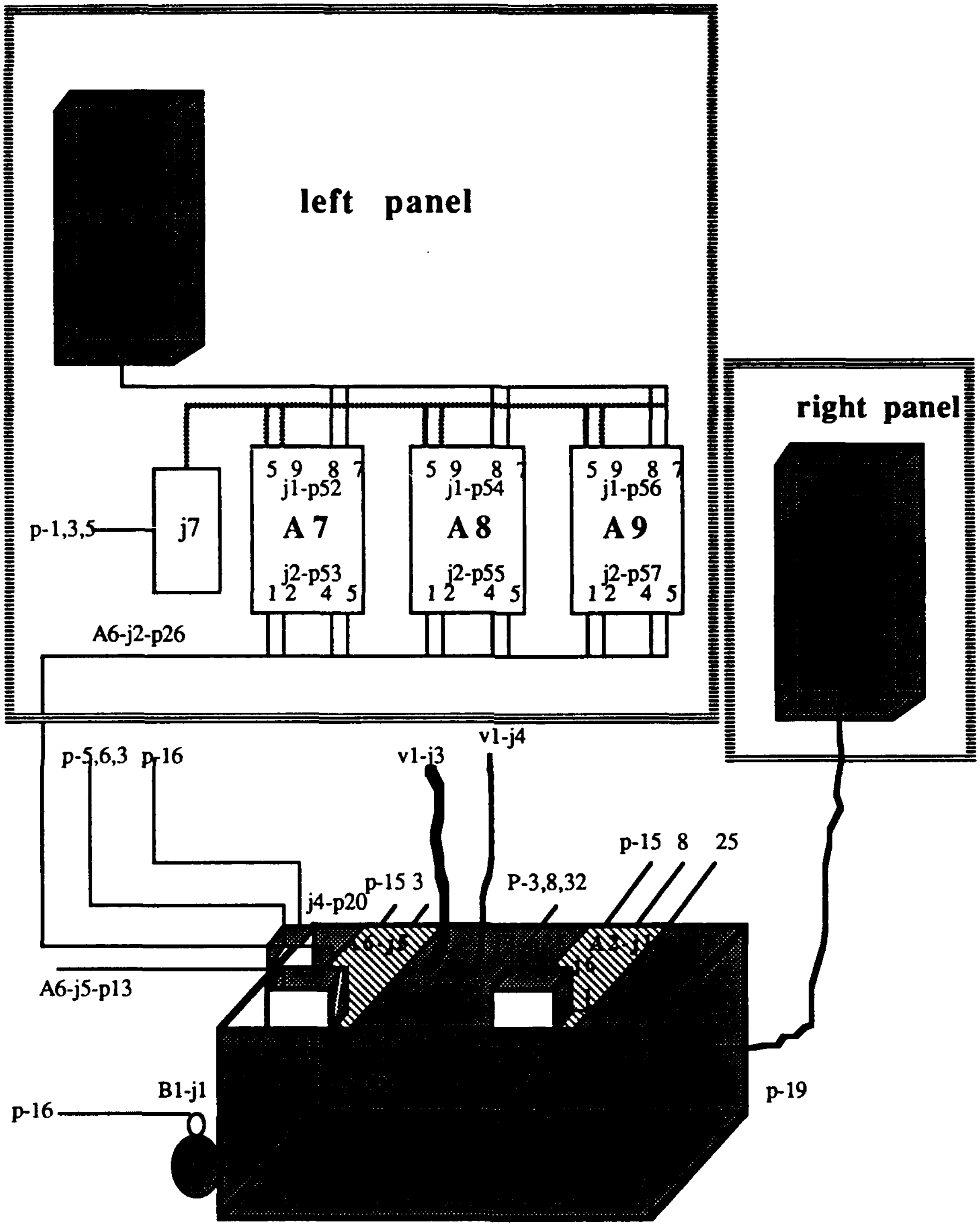

Figure 4 High Vlotage Power Supply Unit Schematic Diagram

3. Inverter Assembly (A2)

The inverter assembly provides the drive power for the high voltage power supply. The inverter assembly receives filtered 600 Vdc from the rectifier filter assembly. When the inverter SCR drive pulses are received from the error amplifier and inverter driver, the 600 Vdc is switched by a bridge inverter circuit, composed of four SCR's, to form a variable frequency squarewave of 1200 V peak-to-peak. The squarewave is coupled by an inverter transformer to the high voltage power supply.

4. High Voltage Power Supply (A2)

The step-up voltage from the inverter transformer is rectified in an offset tap configuration and filtered to furnish two high voltage dc outputs to operate the TWT in a depressed collector mode. Both high voltage outputs are adjustable, from -28 kV voltage to -34 kV voltage (cathode supply) and from -8.9 kV voltage to -10.8 kV voltage (collector supply), while maintaining a 32% depression.

C. MODULATION UNIT

The modulation unit provides modulated grid voltage and filament voltage required by the high power TWT. The solid state modulator consists of a low level modulator drive assembly called the ground level and a floating deck. The floating deck is immersed in FC-77 inside the high voltage assembly A2. The modulator low level drive assembly is located on the top cover of the high voltage assembly. The block diagram of this unit is shown in Figure 5.

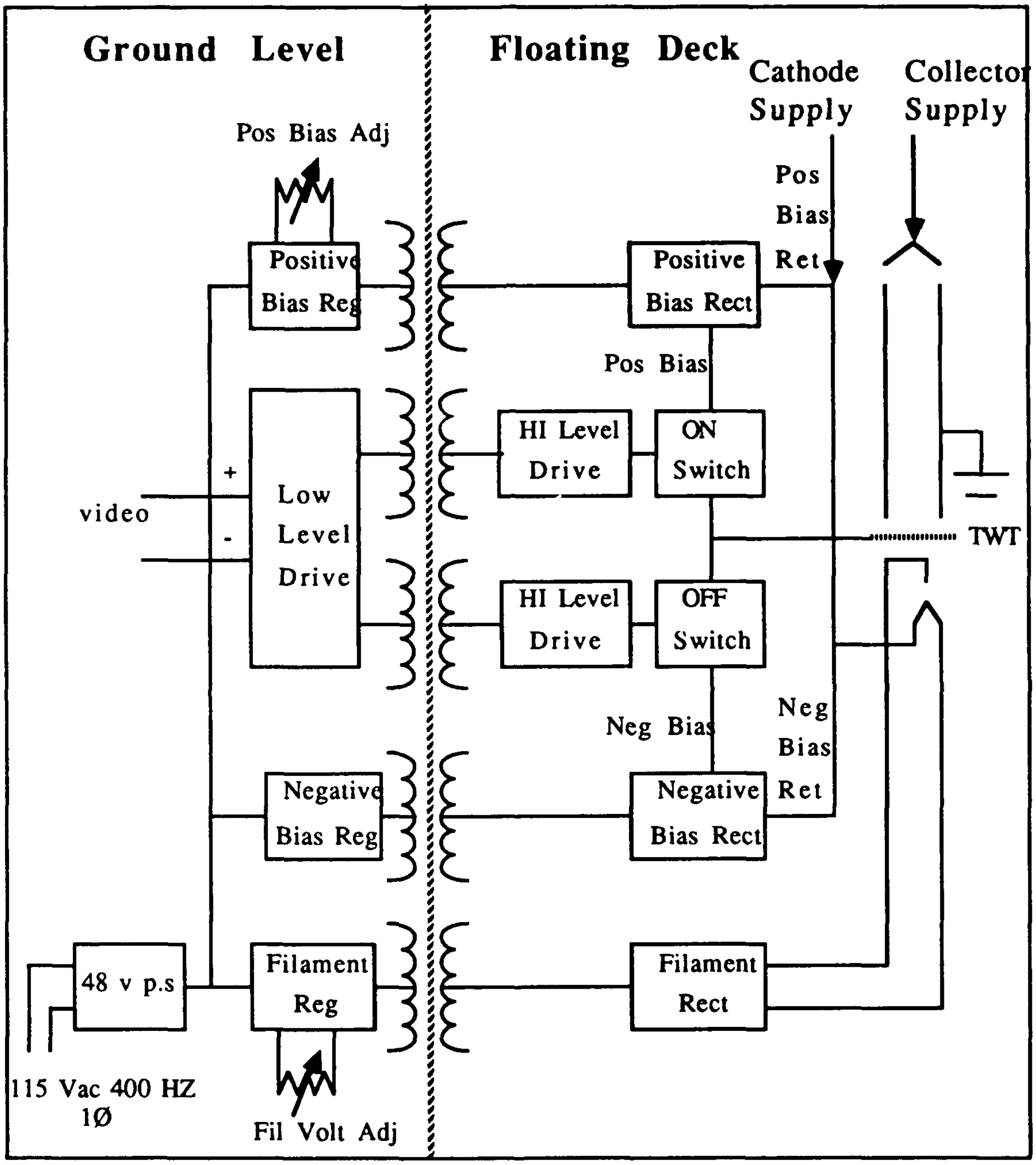

Figure 5 Modulator Unit Block Diagram

1. Low Level Modulator Drive (A6j5)

The low level modulator drive assembly contains the necessary video interface and bias supplies. It provides amplification of the modulator video (mod. video) input signal. The mod. video input signal is differentiated and two outputs are applied to separate drive circuits which generate on and off drive signals corresponding to the video leading and trailing edges. The on and off signals are then coupled through isolation transformers to the floating deck.

2. Floating Deck (A6j2)

The floating deck consists of the on and off Field Effect Transistor (FET) switches and the associated rectifiers and filters for the bias and filament voltages. When on and off triggers are received, these two triggers are amplified and shaped by the high level drive circuits. The signals leaving the high level drive circuits drive the FET on and off switches which modulate the grid. The entire floating deck is enclosed in a Faraday shield to minimize voltage gradients within the modulator. The modulator also incorporates a fail safe feature by limiting the maximum grid pulse width to less than 10 microseconds in the event of a missing off trigger.

D. CONTROL UNIT

The control unit completely controls and monitors the operation of the HPA. Whenever a fault is detected, an appropriate fault indicator is lit, the modulator is inhibited and the body voltage is shut off. All the circuits are located on the control circuit card assembly, mounted in the top front of the HPA cabinet. This unit contains three kinds of monitor circuits:

1. Fault Monitor Circuits.

2. Control Logic Circuits.

3. Test Circuits.

1. Fault Monitor Circuits

There are 20 fault monitors, 8 status monitor circuits and 9 BNC connections to monitor the HPA. They are located on the control panel and are clearly marked.

The fault monitor circuits are divided into three main categories: the interlock monitors, the DC comparator monitors and the pulse monitors. The functions of the categories are shown in Figure 6.

a. Interlock Monitors

A circuit in this category senses the opening of a switch contact to register a fault. The following fault monitors are in this category:

(1) Circuit Breaker Open (j14-20, 21): senses the opening of the switches CB1, CB2 and CB5 located in the upper-right corner of the HPA cabinet.

(2) Coolant Flow (j14-1): monitors the coolant flow through the coolant flow switches (S4, S5), which are located above the TWT, near the throttle valve (TV1). See Figure 9, p. 26.

(3) Coolant Temperature/WG Pressure (j14-19): senses the signal from coolant overtemperature switch (S1) which is right above the heat exchanger (HE1).

(4) Coolant Level (j14-13): monitors the coolant level in the expansion tank through the liquid level switch (S2). The location of S2

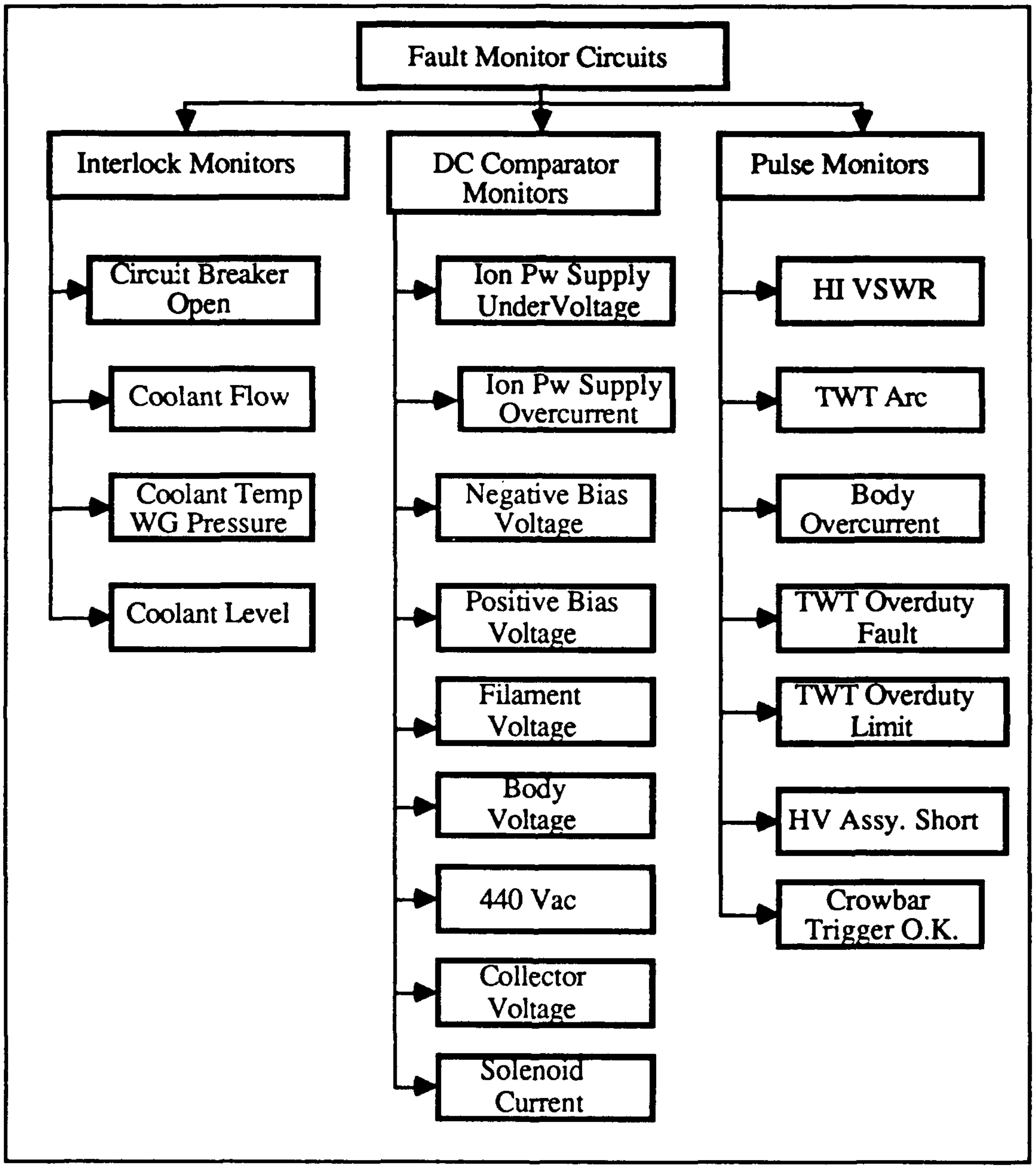

Figure 6 Fault Monitor Circuits Diagram

is under the expansion tank. See Figure 9, p. 26.

b. DC Comparator Monitors

(1) Ion Pump Power Supply Undervoltage (j3-18): senses the ion pump power supply (A4) output voltage. If the ion pump power supply voltage decreases below 1800 V, the output of the comparator is switched to 0 and triggers the indicator driver flip-flop to register a fault.

(2) Ion Pump Power Supply Overcurrent (j3-19): senses the ion pump power supply through a voltage divider. If the ion pump power supply exceeds 10 microamperes, it is determined that there is too much gas present to operate the high power TWT.

(3) Negative Bias Voltage (j3-13): this circuit includes the bias relay logic and the crowbar initiate logic. If the negative bias voltage, with respect to the cathode of the TWT, is increased by more than 5% from -400 V, the negative bias voltage monitor turns off the bias relay drive (j14-14) and generates the crowbar initiate signal.

(4) Positive Bias Voltage (j3-20): monitors that the positive bias voltage remains between +200 V and +400 V, referenced to the cathode of the TWT. Should the voltage moves above or below the values, a fault signal is generated.

(5) Filament Voltage (j3-22): monitors that the filament voltage remains between -9.5 V and -11.5 V, referenced to the cathode of the TWT. If the voltage is not in this range, a fault is generated.

(6) Body Voltage (j8-21): senses an increase in body voltage due to the decrease of the TWT collector voltage. No allowed voltage range is specified.

(7) 440 Vac (j4-1,2): monitors the voltage of the input 400 Vac power line. It registers a fault and opens the circuit breaker CB1, when the voltage does not stay within 400 Vac and 465 Vac.

(8) Collector Voltage (j3-2): monitors that the collector output voltage stays between -8.9 kV and -10.8 kV. A fault is registered if voltage fluctuates outside this range.

(9) Solenoid Current (j2-16): monitors the solenoid power supply output current. An over or under current of 1.0 A from 13 A will cause the circuit to register a fault and turn off the solenoid power supply relay driver.

c. Pulse Monitors

(1) HI VSWR (j4-1): detects the high VSWR condition in the waveguide by examining the reflected RF output samples coupled through CD2 to the RF monitor circuit (A9).

(2) TWT Arc: senses the situation when the TWT sustains an internal high voltage arc from grid to ground. If a TWT arc is detected, the body would be shut off to protect the modulator.

(3) Body Overcurrent (j14-21): senses an increase in body current due to decrease in the TWT collector current. The maximum current allowed is 0.4 A.

(4) TWT Overduty Fault and Limit: This function is performed by a pulse integrator which registers a fault in the event that the TWT duty exceeds 10 microseconds or the TWT remains on continuously for longer than 16 microseconds.

(5) HV Assembly Short (j8-24): senses a grid-to-cathode short circuit condition and provides protection to the modulator.

(6) Crowbar Trigger O.K. (j8-25): senses that the triggered spark gap is fired. This short circuits both high voltage outputs to divert supply energy away from the TWT.

2. Control Logic Circuits

The control logic circuit contains the initial power on and fault control logic. The initial power on circuits activate parts of the HPA's circuits and provide the necessary conditions before the whole HPA system is operated. The fault control logic circuits were designed to accomplish automatic control of the system when a fault occurs after the HPA is operating.

a. Initial Power On

The initial power on circuits start to operate when the primary power is turned on. The following conditions are initiated simultaneously:

(1) The ±15 V power supplies start to supply voltage to the control panel and activate the monitor circuits.

(2) The coolant pump starts the coolant flow which is monitored by coolant time delay circuit. If the coolant does not come up to full flow within four seconds, the 440 Vac is removed by removing the 15 V coolant level switch signal.

(3) The TWT filament starts to warm up, drawing a very heavy initial current. The filament timer is started. Three minutes after

initial power on the filament timer times out. The TWT is ready for high voltage operation and the HV switch is enabled to be turned on.

(4) Sets the HV switch to the ON position to turn on the body voltage. The body voltage attains full voltage approximately one second after HV switch is set to the ON position.

b. Fault Control Logic

To describe the fault control logic involved when a fault occurs, the TWT coolant flow fault (j14-1) circuit, the filament fault circuit (j3-22) and the negative bias fault circuit (j3-13) are used as examples.

(1) TWT Coolant Flow Fault

When a TWT coolant flow fault occurs, one of the coolant flow switches (S4 or S5) opens. This causes the TWT coolant flow fault indicator to light and the generation of an HV inhibit signal. The HV inhibit signal turns off the high voltage and inhibits the modulator. The TWT solenoid will shut off the solenoid power supply. The HPA will remain in the HV OFF or the standby states until the coolant flow is restored and the reset pushbutton switch (S3) on the control panel is pressed and released.

(2) Filament Voltage Fault

The filament fault control logic is triggered when the filament senses a voltage variation of more than +5 or -25 percent from -400 V. When such a voltage variation occurs, the filament voltage regulator fault indicator will light. The body voltage is shut off and the modulator is inhibited. The filament relay drive signal de-energizes the relay in the power distribution assembly to be discussed later, and the timer running

indicator is turned on. If the filament power can be restored within less than one minute, the full three minutes will not have to elapse before HV operation can be resumed; otherwise, it will take the full three minutes to resume HV operation, after the reset pushbutton is released.

(3) Negative Bias Fault

The negative bias voltage regulator controls the negative bias voltage for the TWT and the SSM of the HPA. A negative bias voltage regulator fault condition gets the bias relay logic and the crowbar initiate logic involved. Should the negative bias voltage increase by more than 5 percent from the specified value, the negative bias voltage sense signal triggers the fault flip-flop, which in turn lights the negative bias voltage fault indicator, then turns off the bias relay drive, and finally generates the crowbar initiate signal.

c. Test Circuits

The test circuits contain several built-in test circuits to facilitate adjustment and troubleshooting. Each test circuit is set into operation by means of a toggle switch. When the switch is set to the ON position, the HPA is in the test configuration and can not be operated normally. Any switch in the test position will cause a test status indicator to light. The test circuit can be divided into three categories:

(1) Bias Test: this permits adjustment of the positive voltage between +200 V and +400 V. It is enabled by setting the bias test switch (S1) to the ON position.

(2) The Open Loop Test: this permits adjustment of the cathode voltage with the regulator feedback loop disabled. This mode of

operation is useful in troubleshooting HV breakdown and inverter problems. Setting the open loop test switch (S2) to the ON position brings up the high voltage. The magnitude of this voltage is adjusted by the open loop adjust potentiometer which is located on the control panel right near S3.

(3) The Manual Test: this is accomplished by applying a simulated fault signal to the input of each monitor and observing that the respective fault indicator lights. Since all fault monitors are tested simultaneously, all fault indicators are lit simultaneously. A fault indicator that does not light indicates a defective monitor circuit. Likewise, a fault indicator that does not de-energize after the simulated fault signal is removed and the reset pushbutton (S3) is activated, indicates either a defective monitor circuit or the presence of an actual fault. Several dc input comparator type monitors check the incoming signals for overvoltage and undervoltage conditions and register the faults on respective signal indicators. The manual test switch is a spring-loaded, center 4-pole, double-throw, toggle switch. To enable the separation of the overvoltage situations from the undervoltage situations, the manual test switch checks the overvoltage monitors in position 1 and the undervoltage monitors in position 2.

E. HPA POWER DISTRIBUTION UNIT

This unit distributes the incoming power supplied to the HPA. There are three types of input power: 440 Vac at 400 Hz in 3 phases, 115 Vac at 60 Hz in single phase, and 115 Vac at 400 Hz in single phase.

1 440 Vac 400 Hz 3-Phase Switches (CB, CB2)

The switches control the HPA's rectifier filter assembly (A5) and the cooling pump (B1). It includes filters, switches, relays, and circuit breakers, housed in the power distribution panel (A10). The power lines are shown in Figure 7.

2. 115 Vac 60 Hz Single Phase Switch (CB3)

The switch controls the HPA's Ion Pump (A4) power supply. The power line is shown in Figure 7.

3. 115 Vac 400 Hz Single Phase Switch (CB4)

The 115 Vac 400 Hz power is converted to dc and used mostly in the HPA's control unit. The CB4 switch controls the power flow to the rectifiers PS#1, PS#2 and PS#3.

a. ±15 Vdc (PS#1) and (PS#2)

PS#1 and PS#2 supply the ±15 Vdc power to the control panel (A3) and the Modulation Unit (A6) through the switch S3 via the PS1-6 and PS2-4 wires. The tolerance of the ±15 Vdc for the Modulation Unit is ±5%. The maximum allowed current is 200 microamperes. The detailed wiring is shown in Figure 8.

b. +48 Vdc (PS#3)

PS#3 supplies the +48 Vdc power to the modulator through the positive bias regulator (A7), the negative bias regulator (A8) and the filament regulator (A9).

F. HPA COOLING UNIT

The HPA cooling unit provides liquid cooling for the high power TWT and for the high voltage assembly. The coolant is a Fluorinert compound

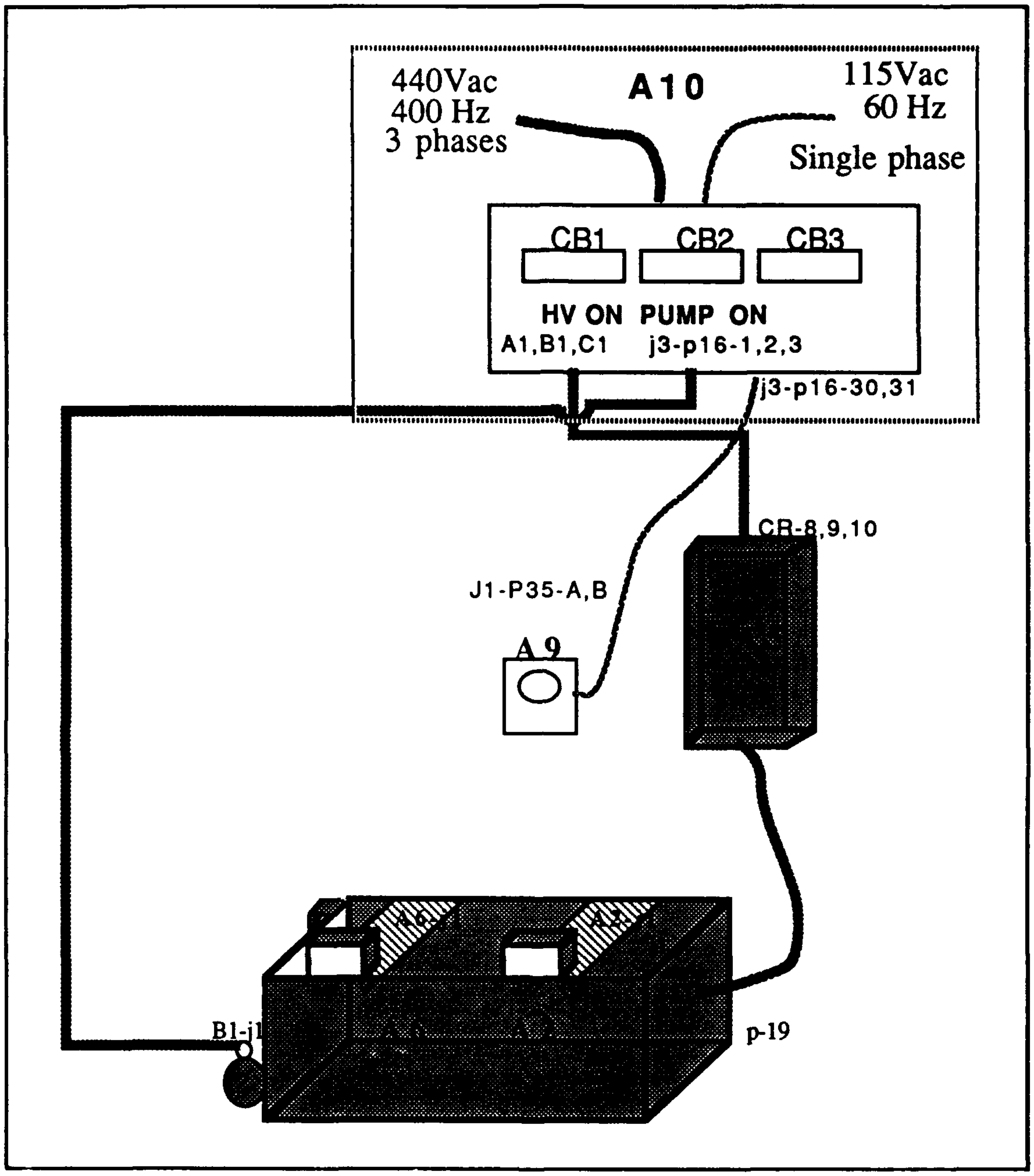

Figure 7 440 Vac and 115 Vac 60 Hz Power Distribution

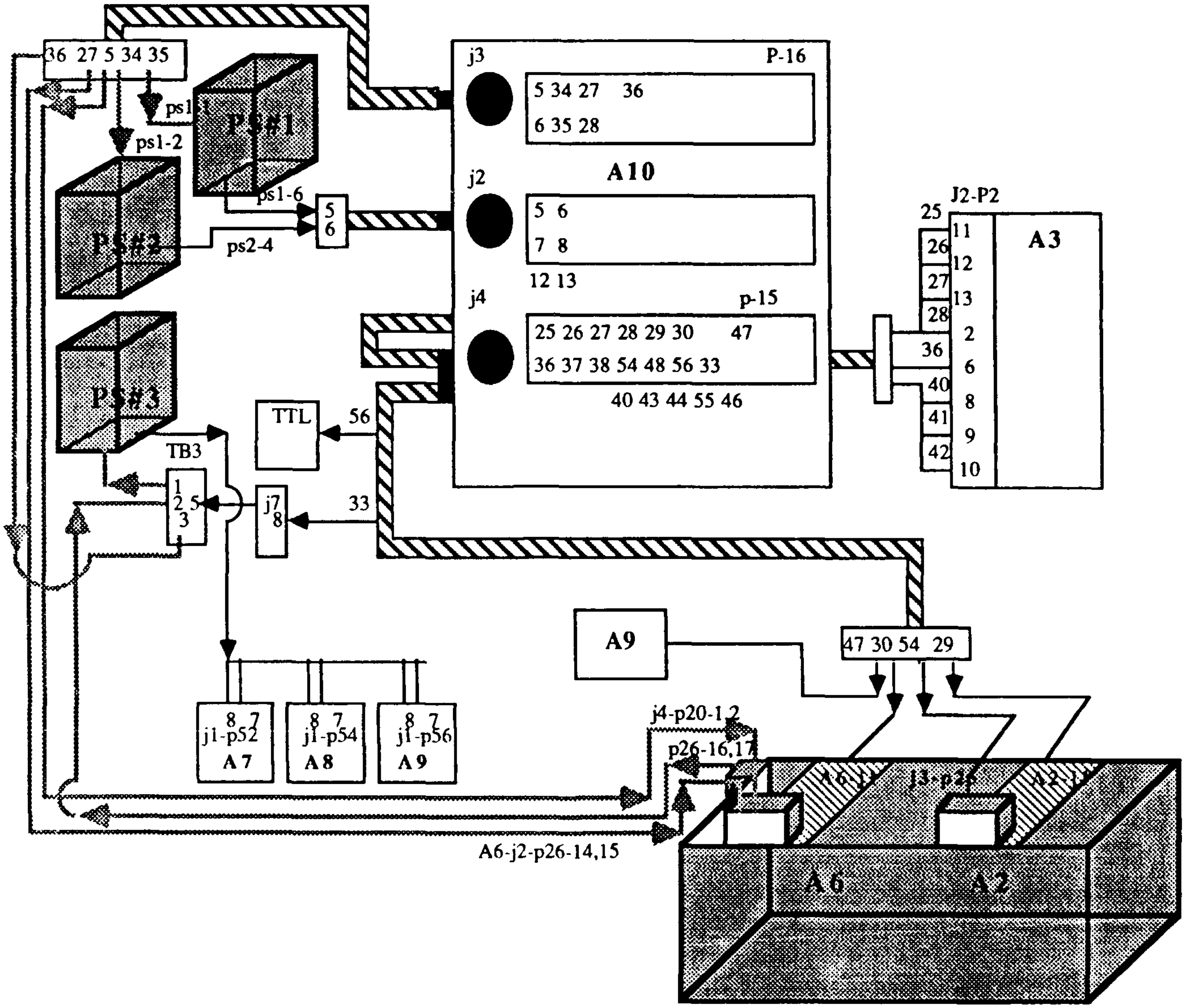

Figure 8 115 Vac 400 Hz and DC Power Lines

(FC-77). The FC-77 coolant also serves as a dielectric to prevent high voltage breakdown in the high voltage assembly. The cooling unit and the coolant flow diagram are shown in Figure 9 and Figure 10.

1. Coolant Pump (B1)

During normal operation, a coolant pump circulates FC-77 liquid at approximately 6 gpm (5 gpm for the TWT and 0.2 gpm for the circulator) through the heat exchanger (HE1), filter, drier (HP6), TWT, AT8 and the HV Tank. Heat in the coolant is transferred to water in the heat exchanger and then dissipated into air in the water filter.

2. High Voltage Tank

The HV tank encloses all the complete high voltage assembly. It serves as the reservoir for the coolant pump. A pressure equalizer line connects the expansion tank to the HV tank. HP12 and HP13 are air bleed valves. HP10 is the drain valve of the HPA tank.

TV1 is a throttle valve which controls coolant flow rate into the TWT. QD1 and QD2 are the quick disconnect valves of the TWT. BV1 is a flow bypass loop to ensure cooling of the coolant pump at all times.

3. Expansion Tank

The expansion tank is equipped with an auxiliary valve (HP3) , a reservoir shut off valve (HP2), a liquid level switch (S2), a vent valve (HP4) and a moisture separator (HP9). All valves and the switch are housed around the expansion tank.

a. Vent Valve (HP4) and Moisture Separator (HP9)

The vent valve (HP4) is a two-way relief valve used to prevent buildup of reservoir pressure or vacuum. The moisture separator

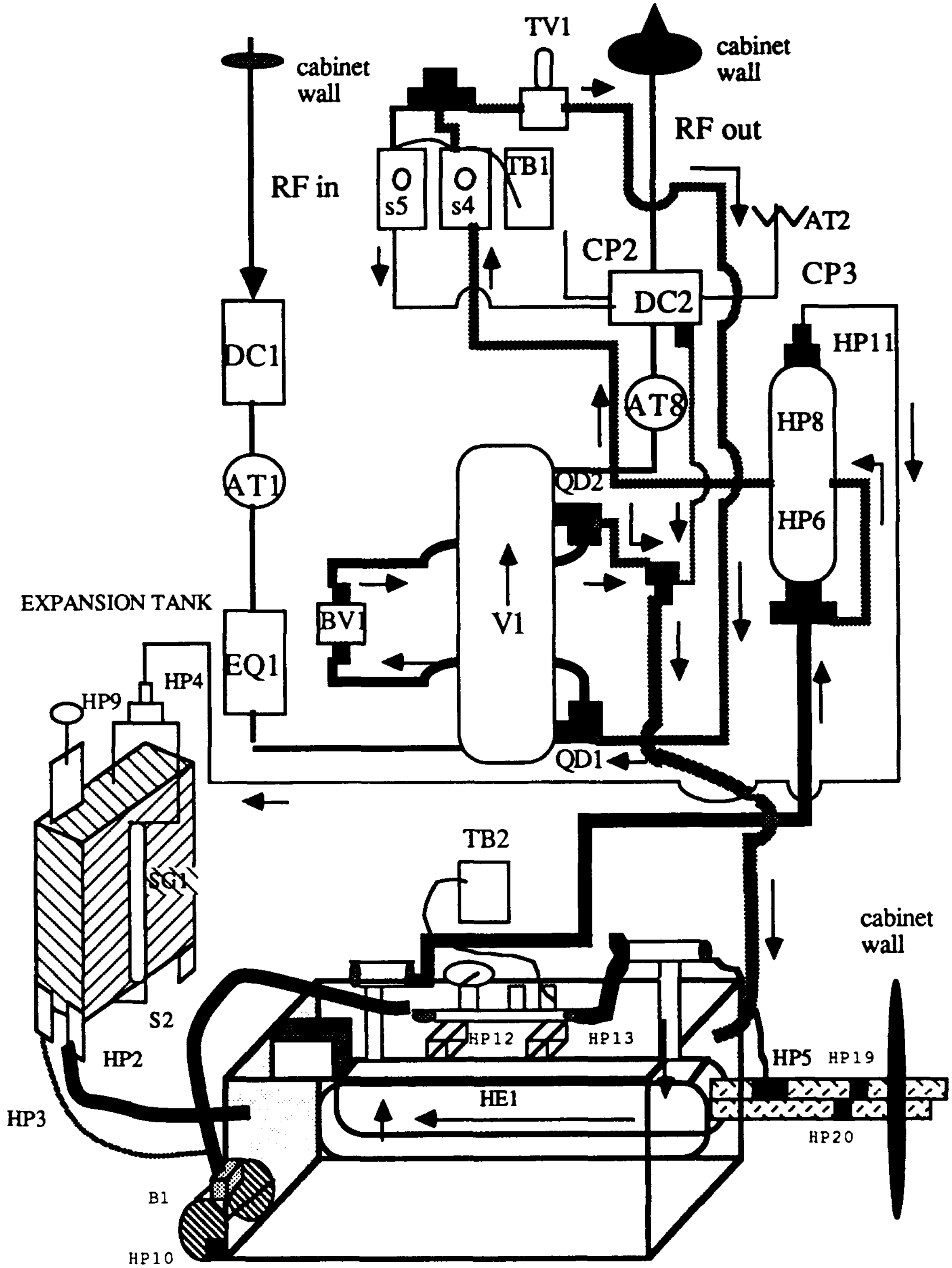

Figure 9 Cooling Unit Block Diagram

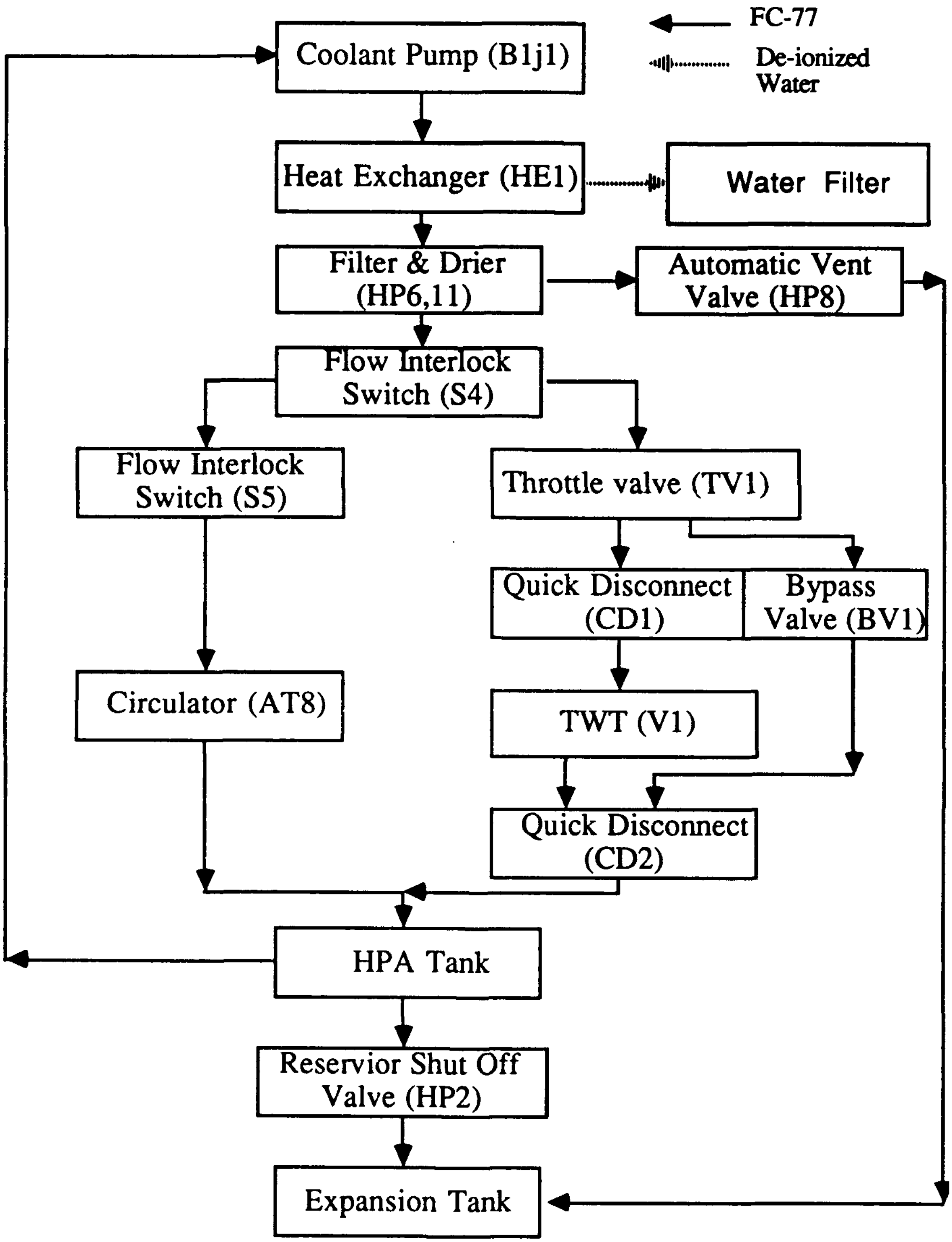

Figure 10 Coolant Flow Diagram

(HP9) is a desiccant device which removes moisture due to any in-breathing through the vent valve. The vent valve and the moisture separator are combined as a unit and used as a fill port on top of the expansion tank.

b. Sight Glass (SG1)

The sight glass is a visual liquid level indicator that is mounted on the expansion tank.

c. Auxiliary Valve (HP3) and Reservoir Shut Off Valve (HP2)

HP2 is the control valve between the expansion tank and the HPA tank. During operation it is always open. HP3 is an auxiliary valve which controls the coolant flow between the cooling pump and the expansion tank. It is always kept closed during normal operation.

d. Liquid Level Switch (S2)

This switch monitor the expansion tank liquid level. If the coolant level becomes too low, a signal is sent to the control card to register a fault.

4. Filter and Drier (HP6), Automatic Vent Valve (HP8) and Miscellaneous

The filter and drier are installed in the coolant line ahead of the HPA tank. An automatic vent valve (HP8) is plumbed into the outlet of the filter and drier and returns accumulated vapor to the expansion tank. The operation of the vent valve is controlled by a float and valve assembly. Vapor or bubbles entering the aerator cause the float to drop and

open the valve. Vapor returns to the expansion tank through a flexible hose. As fluid fills the vent valve, the float rises and closes the valve.

5. Heat Exchanger (HE1)

Heat from the HPA is carried away by the FC-77 coolant and transferred to water through a liquid-to-liquid heat exchanger. A cooling water modulation valve (HP5) is installed in the cooling water line to prevent condensation on the coolant lines in the HPA cabinet. HP19 and HP20 are the water inlet and outlet connections.

6. Water Filter

The water filter is located in a different cabinet which contains a pump, a de-ionizer, a filter, a radiator, a temperature alarm and a water tank. The temperature alarm can be set to a specific temperature to alarm the operator by adjusting the temperature switch which is located in the front panel of the water filter.

III. SYSTEM OPERATION, MAINTENANCE AND TROUBLESHOOTING

This chapter contains the necessary information to operate the HPA. It lists the system operation, maintenance, troubleshooting and testing procedures for the operator. The contents of this chapter are adapted from the *Technical Manual* with some modification. Only those requirements and procedures most directly related to setting up and operating the HPA at NPS are included in this chapter. For further detail, Appendix A contains flow charts of the maintenance procedures adapted from the *Technical Manual.* Appendix B contains flow charts which combine step-by-step instructions of the *Technical Manual* with explanatory notes for troubleshooting.

The HPA is a complicated system to operate. However, its operation and maintenance are relatively safe when proper equipment is used and procedures are followed. Safety precautions toward using the electrical and electronic equipment, the pressurized systems, and toward radiation hazards should be carefully reviewed. See Ref. 1, p. 24 to p. 29 for detailed information.

A. OPERATION

1. Facility Requirements.

1.1 440 Vac 3-phase 400 Hz 45 A (CB1) Service Delta.

1.2 115 Vac 1-phase 400 Hz 10 A (CB4) Service.

1.3 115 Vac 1-phase 60 Hz 80 A Service (CB3, CB5).

1.4 25 GPM flow of water at 45 °F to 110 °F.

1.5 Regulated dry air or nitrogen, 20 to 30 PSI.

1.6 Before applying power to the transmitter, make a visual inspection of the waveguide to assure proper connection. Check the RF output for either an antenna or an adequately rated dummy load connection.

2. **Turn-on Procedures.**

The following procedures are listed step-wise.

2.1 Turn off circuit breaker CB1 (400 Vac) and CB4 (115 Vac).

2.2 Turn on circuit breakers CB2 (Cooling Pump), CB3 (115 Vac 60 Hz), CB5 (115 Vac 60 Hz), S3 (15 Vdc) and S4 (Ion pump).

2.3 Check for leaks in the FC-77 coolant lines. Verify that the auxiliary valve (HP3) is closed and that the reservoir shut off valve (HP2) is open. These valves are located near the bottom of the expansion tank. See Figure 9.

2.4 Bleed air from the high voltage assembly through air bleed valves (HP12, HP13) located above the HV tank which encloses the modulator and high voltage assemblies. Let the HPA run in this mode for at least 5 minutes to assure that no air voids exist in the FC-77 fluid. Then turn off air bleed valves (HP12, HP13).

2.5 Turn off switch S3 (15 Vdc).

2.6 Turn on circuit breakers CB1 (440 Vac) and CB4 (115 Vac).

2.7 Turn on switch S3 (15 Vdc) and wait for the 3-minute filament timer time-out.

2.8 Manually reset the control circuit card if fault lights are present.

2.9 After a reset, if a fault light persists, refer to the fault troubleshooting flow charts.

2.10 Turn on the high voltage switch (HV ON) located on the control panel.

2.11 HPA is now operational.

3. **Turn-off Procedures.**

The following procedures are listed step-wise.

3.1 Turn off the high voltage switch (HV ON).

3.2 Turn off S3 (15 Vdc). This will shut off CB1 and CB4.

3.3 The ion pump switch (S4) can be turned off or left on as desired.

3.4 If the unit has been operating at a high duty cycle for an extended time, it is recommended that following step 3.2 above, CB1 (440 Vac) and CB4 (115Vac) be turned off and then S3 (15 Vdc) turned back on. This allows the FC-77 to circulate and avoids thermal shock.

B. GENERAL MAINTENANCE

The following procedures contain the information required to perform alignments, adjustments and repairs on the equipment which are within the capability of the HPA user.

1. High Voltage Tank FC-77 Fill and Drain

a. Tools, Parts, Material and Test Equipment

(1) 3/8" Drive Socket Set.

(2) Open-End Wrench Set.

(3) Teflon Thread Sealing Tape.

(4) FC-77 Fluid.

(5) Warning Tag.

b. Drain Procedures: Reduce the coolant level in the high voltage assembly

b.1 Turn off CB1 (440 Vac), CB4 (115 Vac), CB5 (115 Vac) and tag the warning sign. This step must be performed before the fluid level is reduced; otherwise, arcing might occur in the high voltage assembly.

b.2 Turn on CB2 (cooling pump), CB3 (115 Vac) and S3 (15 Vdc) to circulate the coolant flow.

b.3 Close the reservoir shutoff valve HP2 to let the circulating coolant flow into the expansion tank.

b.4 Open the auxiliary valve HP3 and be ready to close the valve HP3 at the moment the fluid reaches the tank drain level marked on the sight class (SG1).

b.5 Shut off the auxiliary valve HP3 when fluid reaches the tank's drain well.

b.6 Turn off CB2 (cooling pump), CB3 (115 Vac) and S3 (15 Vdc).

b.7 Remove and replace failed sub-assembly in accordance with the appropriate procedures.

c. Fill Procedures: Add coolant to the high voltage assembly after the replacement of sub-assemblies

c.1 Turn off CB1 (440 Vac), CB4 (115 Vac) and CB5 (115 Vac) and the tag warning sign.

c.2 Fill the FC-77 fluid through the fill port after removing the vent valve (HP4).

c.3 Open the reservoir shutoff valve (HP2) to let the coolant flow into the HPA tank.

c.4 Bleed air from the high voltage assembly through air bleed valves (HP12, HP13) located on the modulator and high voltage assembly. This will allow proper draining of the FC-77 expansion tank.

c.5 Turn on CB2 (cooling pump), CB3 (115 Vac) and S3 (15 Vdc) to circulate the coolant.

c.6 After 5 minutes of running, bleed air from the high voltage tank before turning on high voltage.

c.7. Turn off air bleed valves (HP12, HP13).

d. Replace coolant filter HP6

d.1 Turn off CB1 (400 Vac), CB2 (cooling pump), CB3 (115 Vac), CB4 (115 Vac), CB5 (115 Vac), S4 (ion pump) and tag warning sign.

d.2 Remove the automatic vent valve HP8 and the check valve HP11 to facilitate removal of the filter cover and all assemblies located on the right side of the cabinet near the rectifier filter (A5).

d.3 Loosen 2 clamps securing the filter cover and remove the cover.

d.4 Replace filter.

d.5 Reverse step d.3 and then step d.2.

d.6 Turn on CB2 (cooling pump), CB3 (115 Vac), and S3 (15 Vdc) to circulate the coolant.

d.7 After 5 minutes of running the coolant pump, and before turning on high voltage, bleed air from the air bleed valves (HP12, HP13).

2. High Power TWT Removal and Replacement

a. Tools, Parts, Material and Test Equipment

(1) 3/8" Drive Socket Set.

(2) Allen Wrench Set.

(3) Warning Tag.

(4) Modulator Test Plug.

(5) Tektronix 465 Scope (or equivalent).

(6) Tektronix 100-to-1 (1500V) Probe.

(7) Digital Voltmeter Fluke 8080 (or equivalent).

(8) Pulse Generator 101A (or equivalent).

b. Removal and Replacement Procedures

b.1 Turn off circuit breakers CB1, CB2, CB3, CB4, CB5, S3, S4 and tag the warning sign.

b.2 Remove high voltage plugs from the TWT cathode supply and from the modulator. Ground modulator output terminals with "chicken sticks" before continuing.

b.3 Remove top and bottom coolant hoses quick-disconnect fittings located on the TWT.

b.4. Remove high voltage plug from the top of the TWT collector supply.

b.5. Remove solenoid voltage supply plug.

b.6 Disconnect the plug from the ion pump power supply.

b.7 Disconnect the input and output waveguides from the TWT. The TWT is heavy (approximately 80 lbs) and requires 2 persons to remove it. One person must hold the TWT in position while the final bolts are removed.

b.8 Remove the 6 bolts holding the TWT.

b.9 Remove the TWT by lifting it and pulling straight out from rear of the cabinet.

b.10 Install new TWT by performing steps 3 through 9 in reverse order. One person must hold the TWT in position while the initial bolts are attached.

b.11 Check that CB1 is turned off.

b.12 Connect the modulator test adapter to the modulator and TWT.

b.13. Connect a pulse generator to j1, the video buffer circuit located on the inside lower left wall of the cabinet. Set the generator for 3 V peak, 1 microsecond pulse width and 1 kHz PRF.

b.14 Connect the scope with the 100-to-1 probe to the TWT grid test point on the modulator adapter. Scope ground goes to the TWT cathode test point.

b.15 Turn on CB3, CB4, CB5, S3 and S4. ***Do not turn on CB1 or CB2.***

b.16 After the 3 minutes delay is over, turn on the bias test switch located on the control panel.

b.17 Adjust variac on the ac regulator located on upper left side of the cabinet for a 600 V to 850 V grid swing.

b.18 Turn off bias test switch.

b.19 Turn off CB3, CB4, CB5, S3 and S4.

b.20 Disconnect the pulse generator, the scope and the modulator test adapter.

b.21 Connect high voltage cable (cathode supply) to the modulator and the TWT.

b.22 Connect the digital voltmeter to j15 located on the control panel to measure cathode voltage.

b.23 Turn on circuit breakers CB1, CB2, CB3, CB4, CB5, S3 and S4.

b.24 After the 3 minutes delay is over, high voltage should be present[1].

b.25 Adjust pot on the error amplifier card located on the right hand-side on top of the HPA for the -2.7 to -3.4 V. The actual voltage is the digital voltmeter reading multiplied by 10,000.

b.26 Return the equipment to normal condition.

3. Solenoid Power Supply Alignment

a. Alignment Procedures

a.1 Turn the 15 Vdc switch S3 off.

a.2 Use a clip lead to connect pin 12 of U39 to ground on the control panel.

[1] On initial turn on of a new TWT, high ion current could be encountered. Ion curent must be below 10 microampers before the ion current fault can be reset.

a.3 On the HPA power distribution unit, set the coolant pump circuit breaker CB4 and the 15 Vdc switch S3 to on.

a.4 On the bottom solenoid power supply adjust the current control fully counterclockwise, and the voltage control fully clockwise.

a.5 On the top solenoid power supply, adjust the voltage control fully counterclockwise, and the current control fully clockwise.

a.6 Remove the connector from j2 on the right side of HPA cabinet.

a.7 Turn on the two solenoid power supplies.

a.8 Adjust voltage control on the top power supply until the meter reads 120 Vdc.

a.9 Turn off both circuits breakers on the supplies and attach connector to j2.

a.10 Turn on both circuit breakers and adjust the current control on the bottom power supply until the current meter indicates 13 A.

a.11 Readjust voltage control on the top power supply as necessary to equalize voltage readings on both supplies. Small differences in current readings are due to meter errors.

a.12 Turn off the 15 Vdc switch on A10 and remove the jumper attached in step a.2 from the control card assembly.

a.13 Turn the 15 Vdc switch to on. The solenoid power supply will automatically come on during the power on sequence.

C. SYSTEM TROUBLESHOOTING

1. Detection By Fault Monitor Circuits

Three kinds of fault monitor circuits are used in the HPA. They are the interlock monitors, the dc comparator monitors and the pulse monitors. Each monitor circuit has a different detecting approach depending on the subject being monitored.

a. Detection By Interlock Monitors

This type of circuit simply senses the opening of a switch contact to register a fault. A typical circuit is the coolant level switch (S2) monitor. The coolant level switch (S2) is normally closed. When the coolant level is too low, the switch is opened to remove the +15 V input. This causes the coolant level circuit flip-flop to switch to the fault position, register the fault and turn the coolant level indicator on.

b. Detection By DC Comparator

This type of monitor operates on the principle of comparing a dc voltage level with a fixed voltage reference. The DC voltage signal and the reference voltage are each an input to a differential amplifier comparator integrated circuit. When the DC voltage signal exceeds the reference, the differential switches its output from +15 V to 0. The comparator output, which is connected to an indicator driver flip-flop, triggers the flip-flop to register a fault. A typical monitor circuit is the ion power supply undervoltage monitor port (j3-18). The ion pump power supply (A4) voltage is sampled and sent to the control panel j3-18. The comparator compares it to the reference voltage (3.15 V). If the voltage sample is lower than the reference voltage, the undervoltage monitor will reg-

ister a fault and light the indicator. It generates the MOD INHIB signal which shuts off the body voltage. The test points PTP35 and PTP36 are provided to test the voltage source. The circuit is drawn schematically as Figure 11.

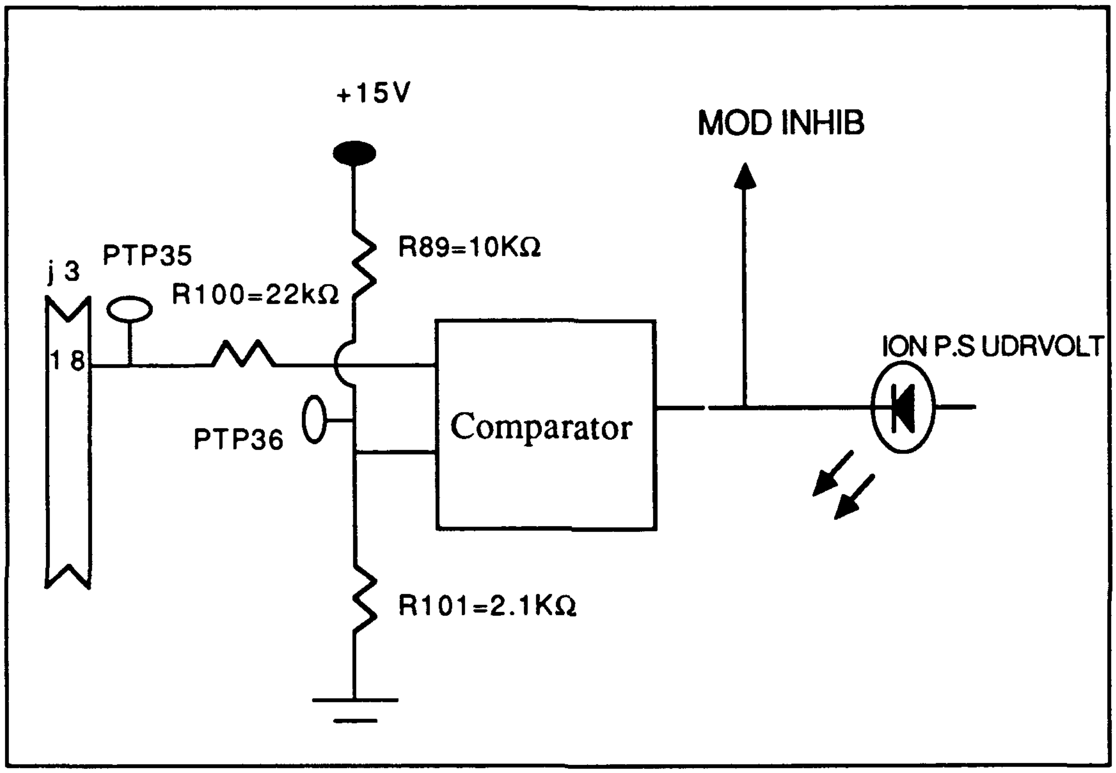

Figure 11 Ion Power Undervoltage Circuit Schematic Diagram

c. Detection By Pulse Comparator

The pulse monitor works like the DC comparator. A typical monitor of this type is the body overcurrent monitor. A positive 8 V cathode pulse is sampled from the cathode current transformer located in A2. This voltage is compared to the negative 7.8 V collector current pulse. Their sum results in a net positive pulse of 0.2 V. If the TWT collector current decreases due to an increase in the body voltage, the net positive

pulse voltage will increase. Should the positive pulse exceed the threshold voltage of 0.6 V, the output of the comparator will be switched to 0 and a fault will be registered.

2. General Troubleshooting

There are two possible means of entry into the troubleshooting procedures:

(1) From a scheduled maintenance test: when a fault is sensed during a scheduled maintenance test, proceed to the relevant troubleshooting flowchart. Use the troubleshooting flow chart to isolate a fault down to a faulty assembly. After the fault is isolated, use the parts location diagram to draw and locate the replacement item. Corrective action may be accomplished. Read the system maintenance procedures for repair instructions.

(2) From an operation malfunction: whenever an equipment malfunction is observed in the course of normal operation, consult the appropriate troubleshooting flowchart. After a fault is detected in the equipment, the primary tool for fault isolation is the troubleshooting flowchart. These charts provide step-by-step instructions in a visual form. Entry into the charts at the appropriate point is accomplished by means of the troubleshooting index which is listed at the beginning of Appendix B.

The procedures contain various YES/NO decision blocks which localize the malfunction to particular functions within the equipment. If an improper exit is made from the decision block, the steps are easily retraced on the flowchart to the decision block where a proper exit can then be made.

3. Solid State Modulator Phase Measurement

There are stringent phase stability requirements on the transmitter. The phase measurement setup is shown in Figure 12 for the verification of phase stability over a single pulse or a pair of RF pulses using a phase bridge.

a. CW Input Phase Measurement

a.1 Before starting the procedure, verify that the input RF signal level is the same as that listed in Appendix C by measuring it from the 10 dB input coupler (DC1).

a.2 Set both attenuators to 5 dB.

a.3 Turn on the HPA following the operation procedures.

a.4 Check if the observed positive detector or inverted negative detector output are similar to Figure 13.

a.5 Adjust the phase shifter until a null occurs. Alternately adjust the attenuators for the sharpest possible null. Keep one of the attenuators to 0 dB. This provides the maximum possible input signal from both arms and gives the best measurement sensitivity. Figure 14 shows a typical output.

a.6 To provide maximum phase change readability and to compensate for scope DC offset limitations, adjust the phase shifter until the scope display looks similar to Figure 15.

a.7 Change the scope display to AC coupling and adjust vertical deflection for maximum sensitivity. Adjust the phase shifter to obtain a display as in Figure 16.

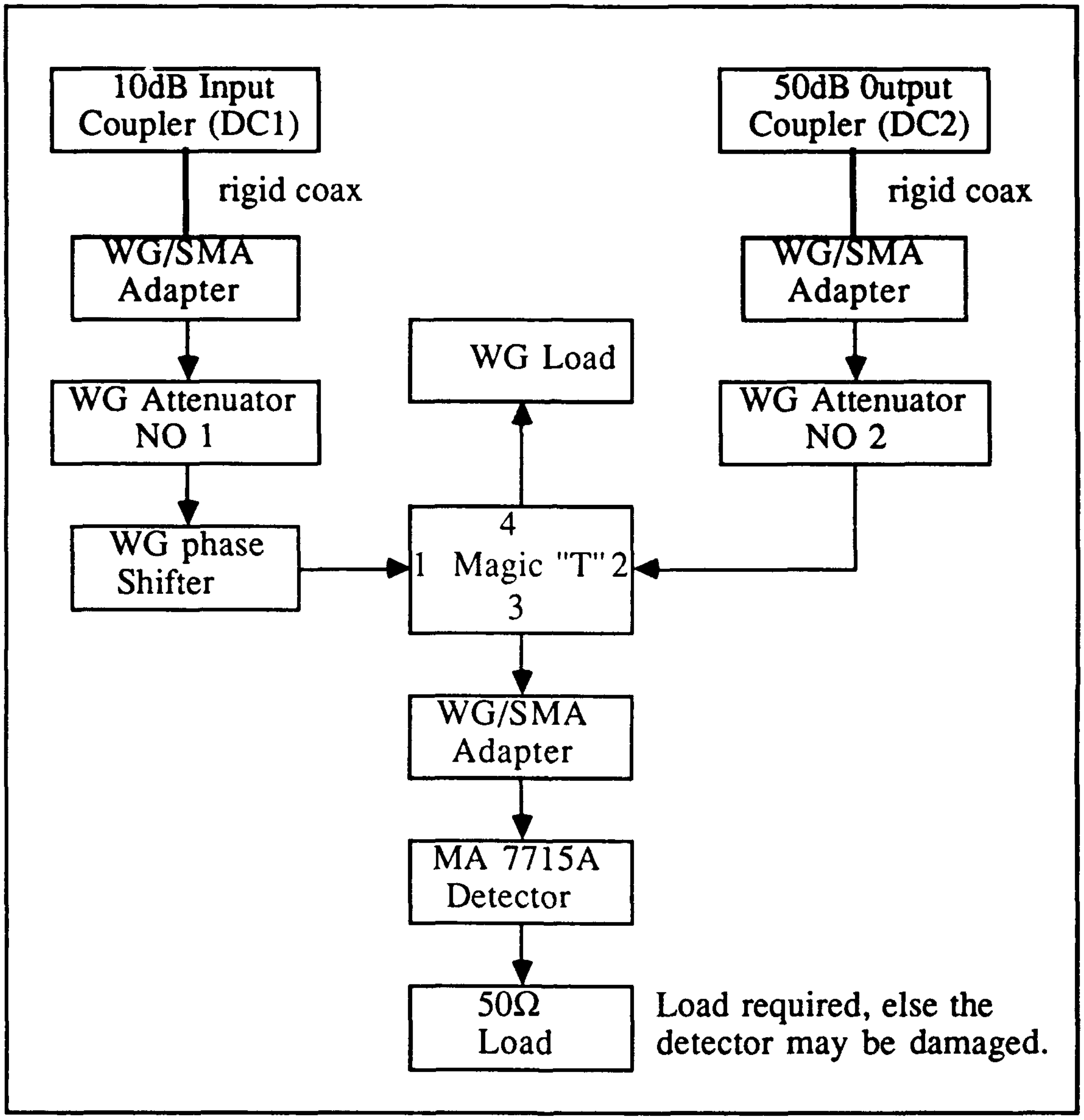

Figure 12 Phase Measurement Setup

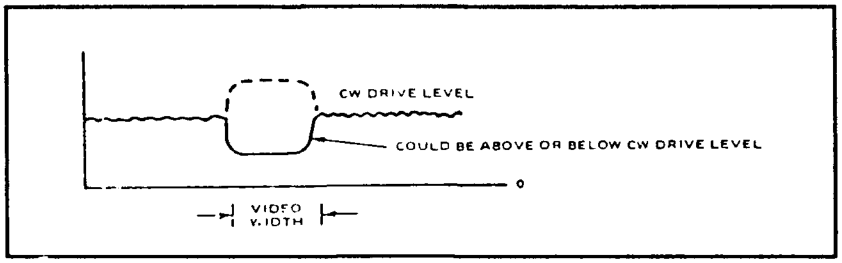

Figure 13 Initial Detection

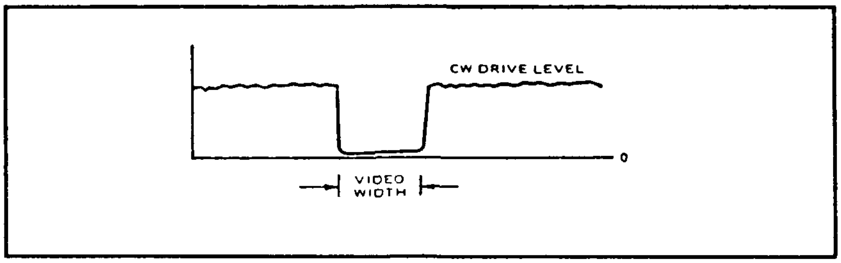

Figure 14 Phase Shift Adjustment

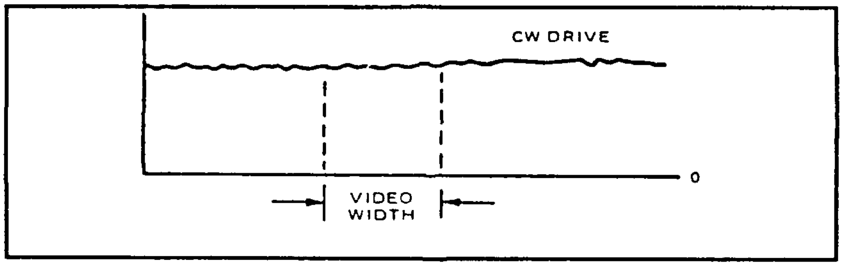

Figure 15 DC Offset Limitation Phase Shift Adjustment

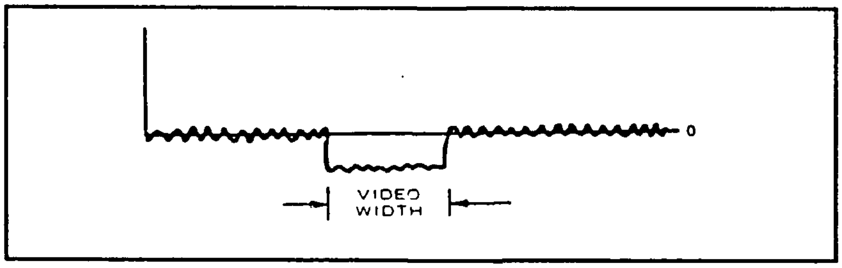

Figure 16 AC Vertical Deflection Phase Shifter Adjustment

b. Pulse RF Phase Measurement

b.1 The triggering scheme used in this measurement is shown in Figure 17. Adjust the pulse width and delay of pulse generator #2 so that it falls within the transmitter video pulse.

b.2 Verify the input RF signal level by measuring the output of the 10 dB input coupler (CD1) using a power meter.

b.3 Phase bridge setup is identical to the Figure 12.

b.4 Turns on the HPA.

b.5 Figure 18 shows a typical scope display prior to the null adjustment.

b.6 Set the pulse generator for internal triggering while initially adjusting the null. After setup, externally trigger the pulse generator from the inverter for a better display.

b.7 Adjust the phase shifter for a null. Alternately adjust the attenuators for a sharp null and note that it is possible to set a false null if both attenuators are adjusted for high attenuation.

b.8 Ideally, one attenuator should read zero. Figure 19 shows the expected waveform.

b.9. Back off on the phase shifter. The detector output will appear like Figure 20.

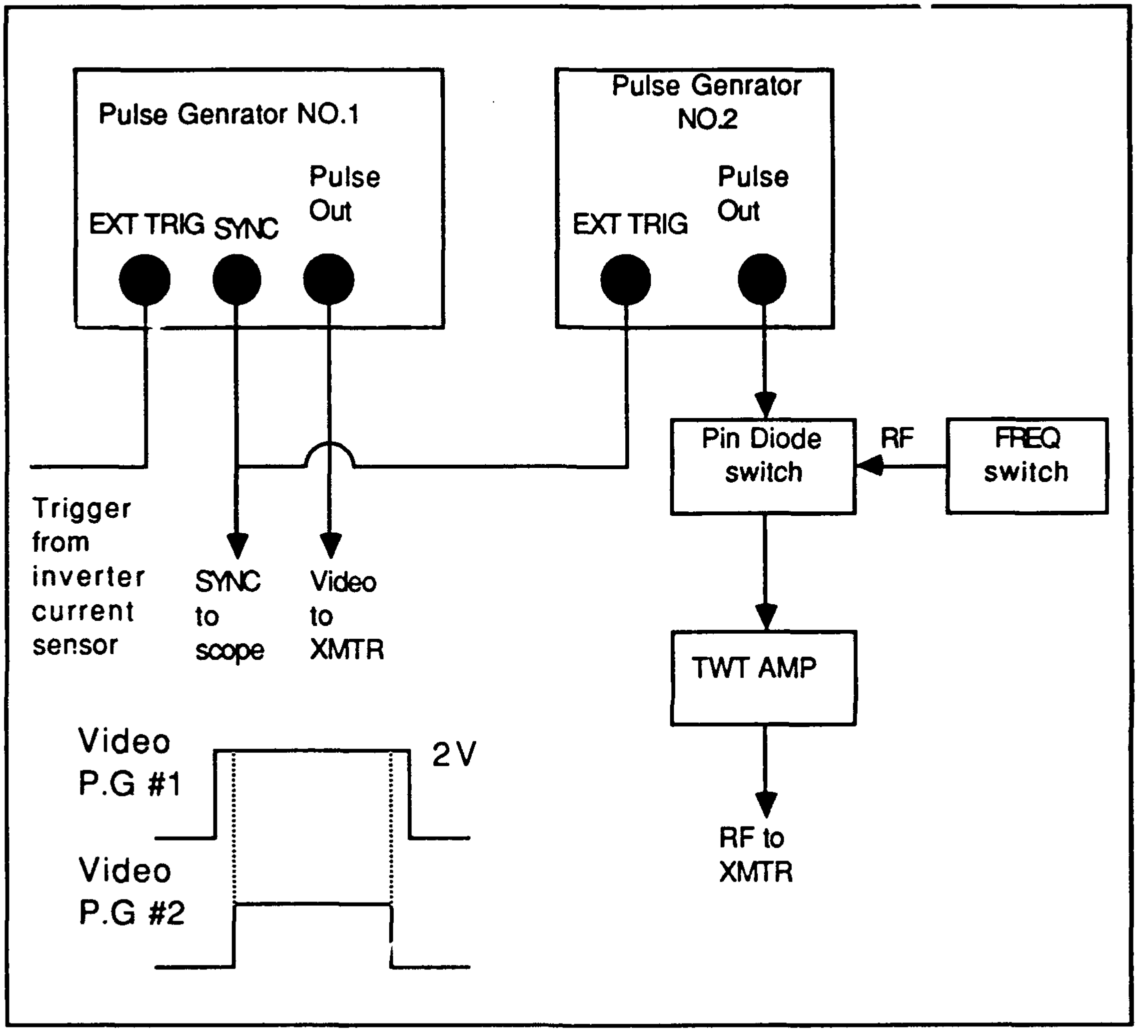

Figure 17 Pulse RF Setup

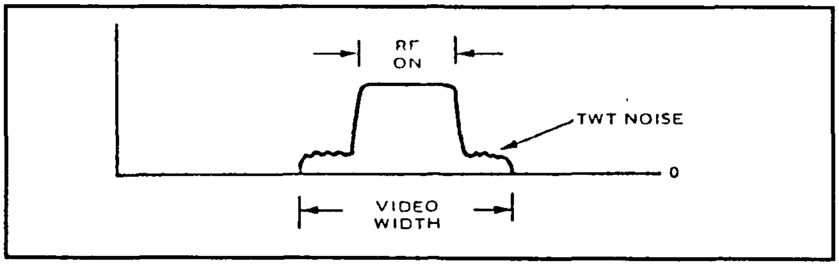

Figure 18 Typical Detector Output Prior To Null Adjustment

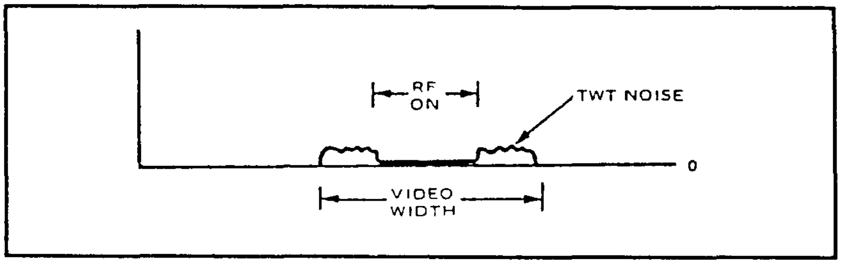

Figure 19 Detector Output After Null Adjustment

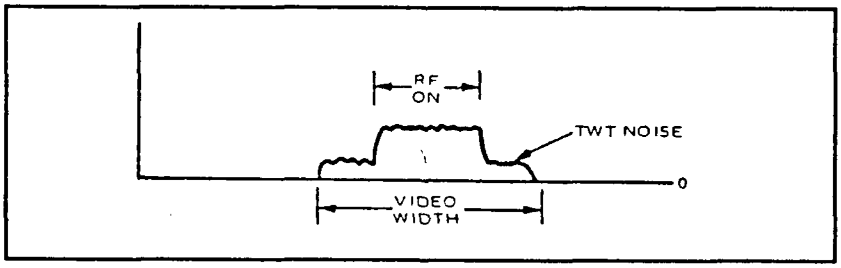

Figure 20 Detector Output After Phase Shifter Is Adjusted To View Phase

IV. CONCLUSIONS AND DISCUSSIONS

This thesis can be used as an operations and maintenance manual for the HPA as it was originally designed. On the other hand, having a deeper understanding of the system, some changes may be made to better utilize it.

The HPA is intended to be used as the final stage amplifier for an instrumentation radar system for studying propagation effects and sea clutter characteristics outside the Monterey Bay. Since the peak output power of the HPA is fixed, one way to increase the detection range or to improve the probability of detection (or equivalently, data accuracy) is to increase the pulse width. What can be done immediately is to adjust the TWT Overduty (A3R261) and the TWT Overduty Fault (A3R195) variable resisters located on the control panel to go beyond the 10 microseconds preset limit.

The extent to which the pulse width can be increased depends on the capability of the cooling system to remove heat from the HPA. Since the long term duty cycle of the HPA is specified at 0.08 while the system runs safely at a short term duty cycle of 0.425 for 1 millisecond before the 0.08 long term duty cycle is restored [Ref. 2], it is clear that the HPA can handle a pulse width of 0.4 millisecond at a 200 Hz pulse repetition rate. Further study on increasing the pulse width is desirable.

Another modification being contemplated is to replace the 400 Hz input power with regular 60 Hz power. With the exception of the coolant pump which can be easily replaced, all the 400 Hz input power is con-

verted to DC before it is used. The system can run on 60 Hz power if appropriate power supplies can be found to feed the required 600 V, 15 V and 48 V dc power directly to the proper contact points. The system can then be moved away from the few 400 Hz generator at NPS.

APPENDIX A SYSTEM OPERATION AND MAINTENANCE FLOWCHARTS

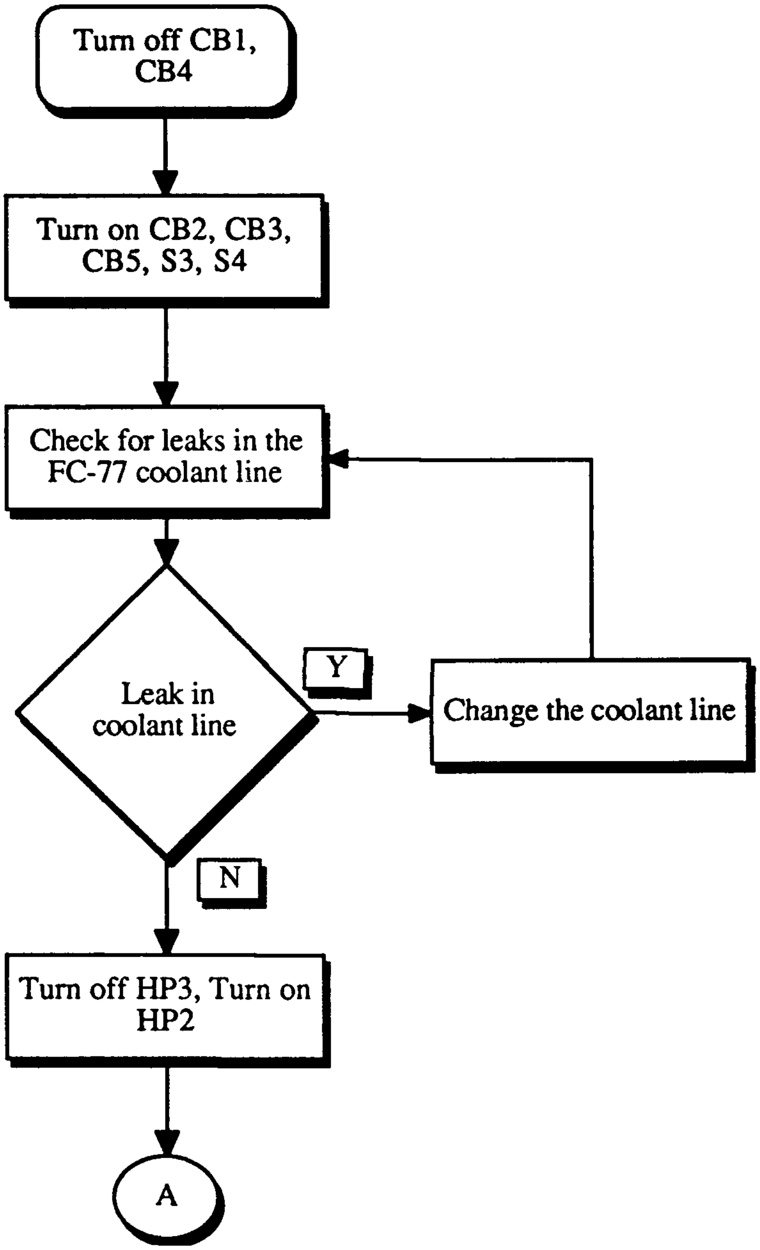

Figure A.1 HPA Turn-On Operation Flowchart

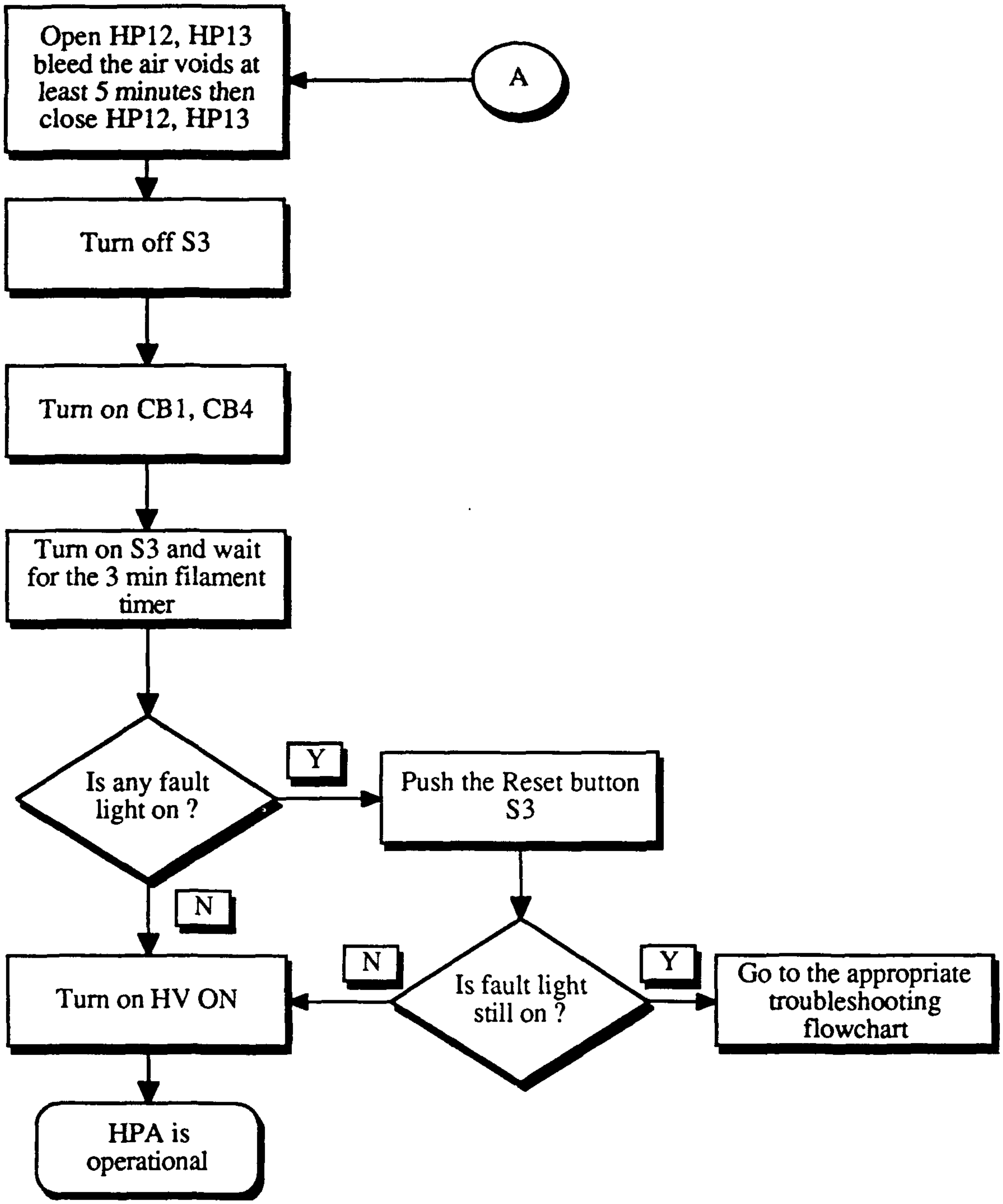

Figure A.1 HPA Turn-On Operation Flowchart (continued)

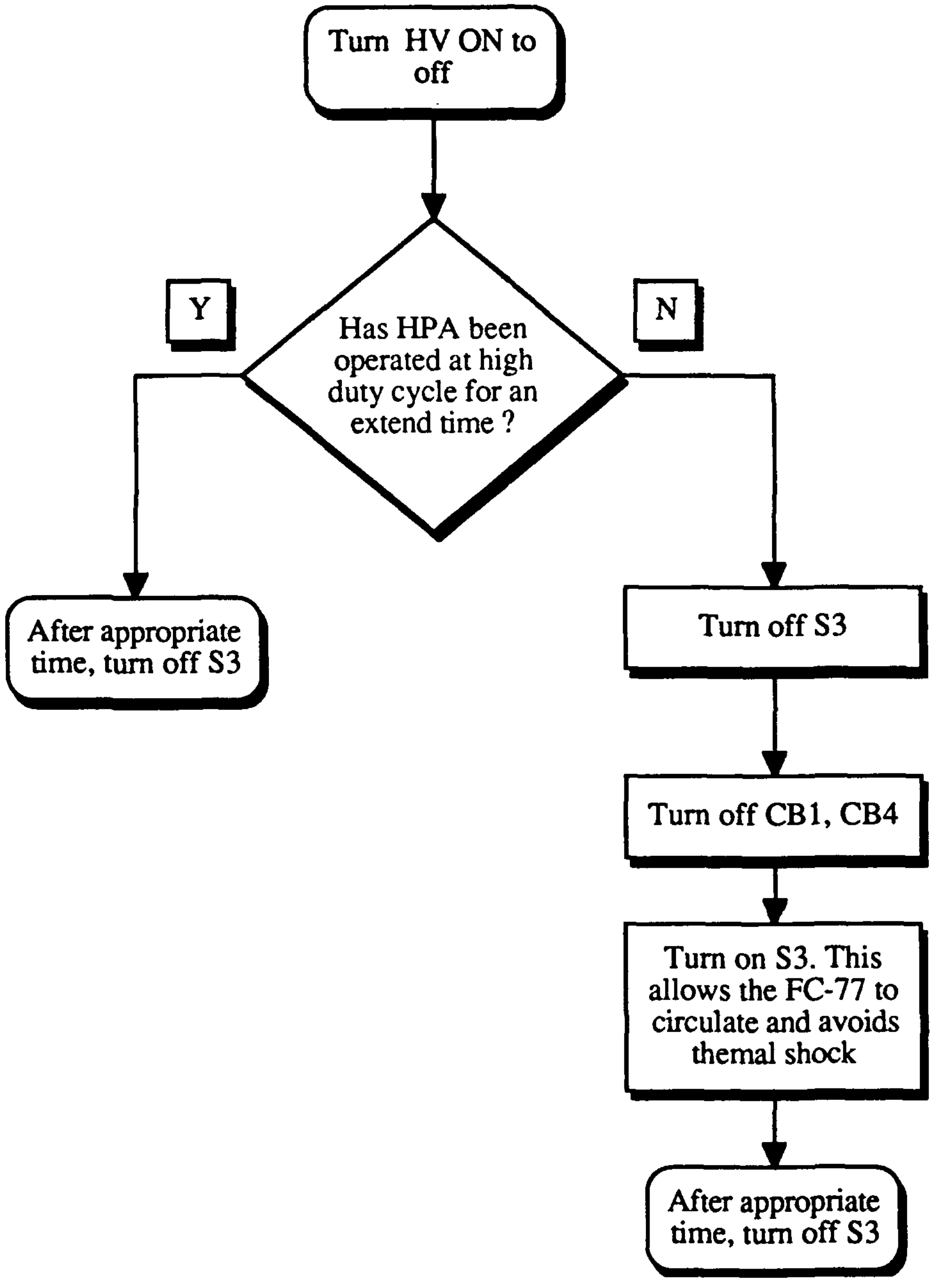

Figure A.2 HPA Turn-Off Operation Flowchart

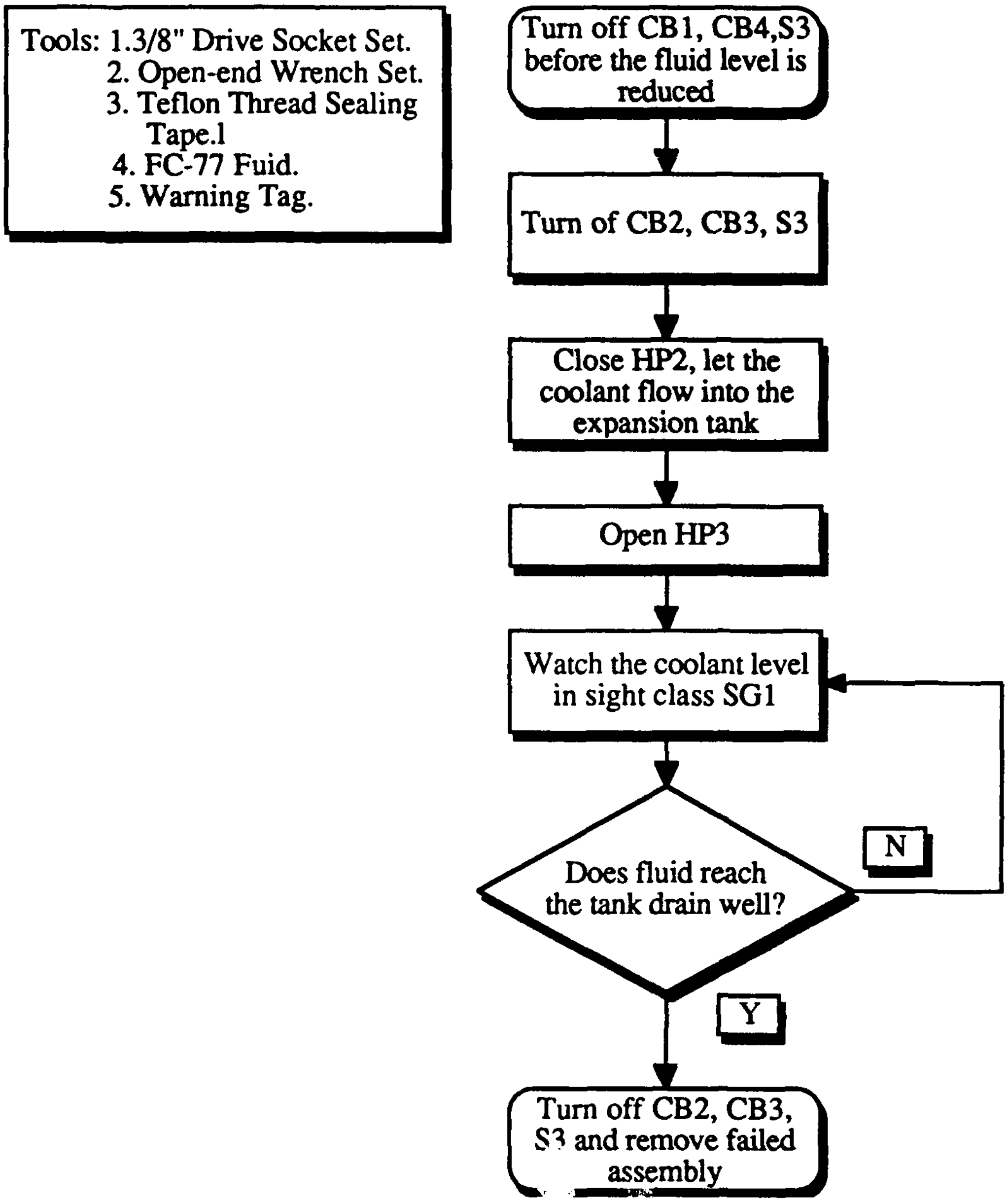

Figure A.3 High Voltage Tank FC-77 Fill And Drain Maintenance Flowchart

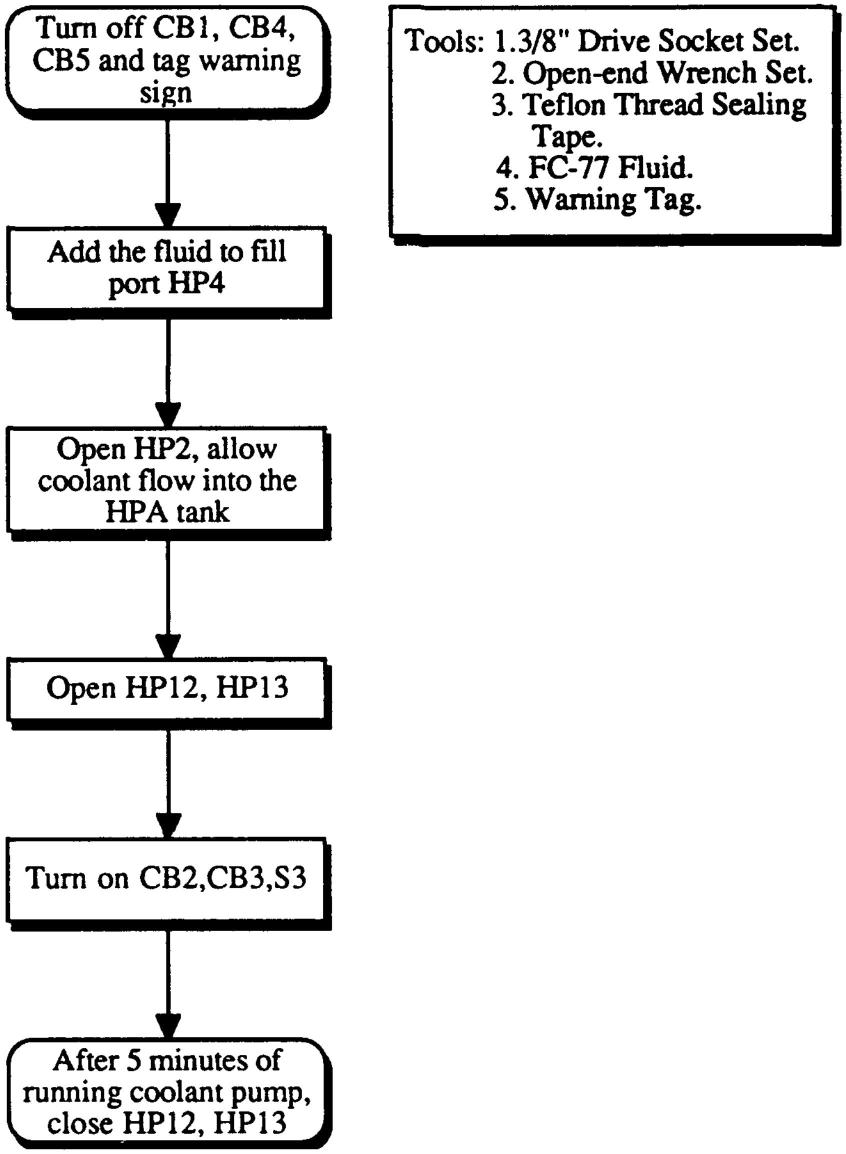

Figure A.4 High Voltage Tank Adding Coolant Maintenance Flowchart

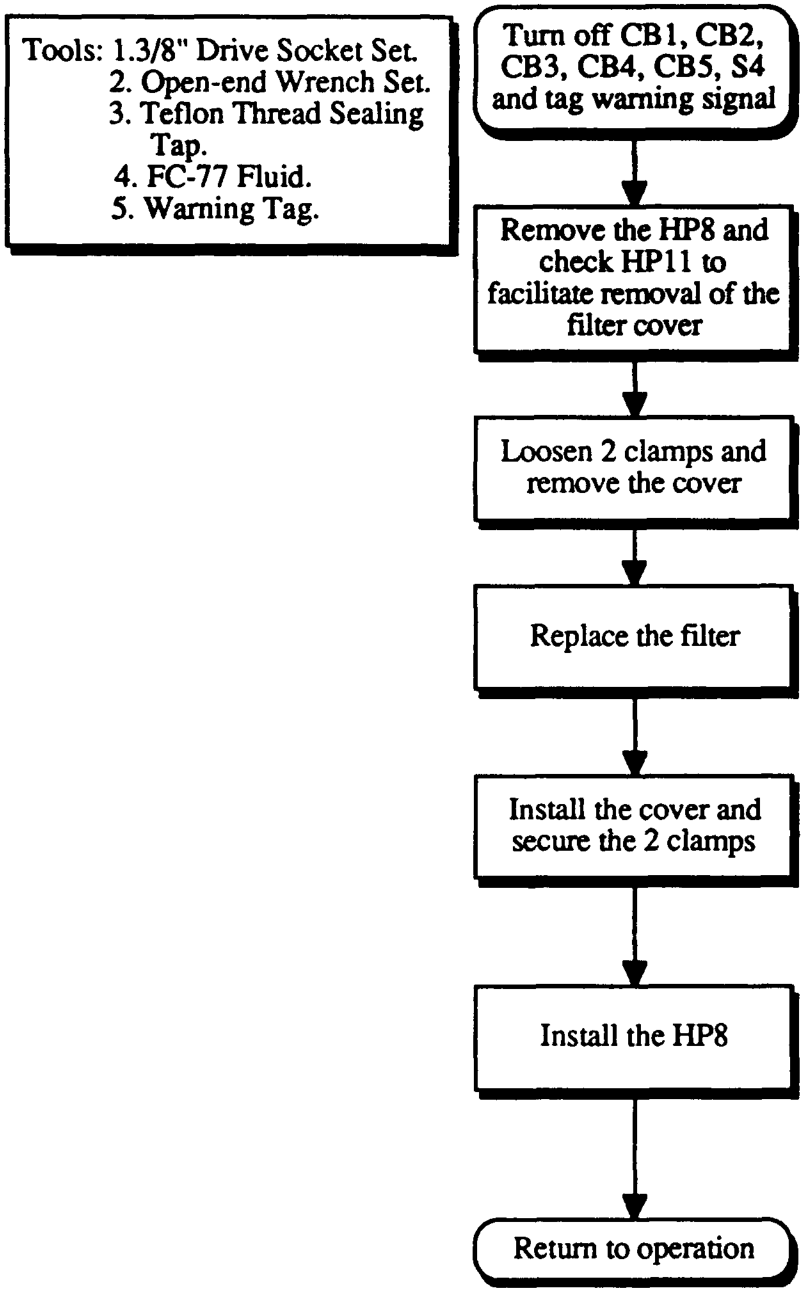

Figure A.5 Replacing Cooling Fluid Filter Maintenance Flowchart

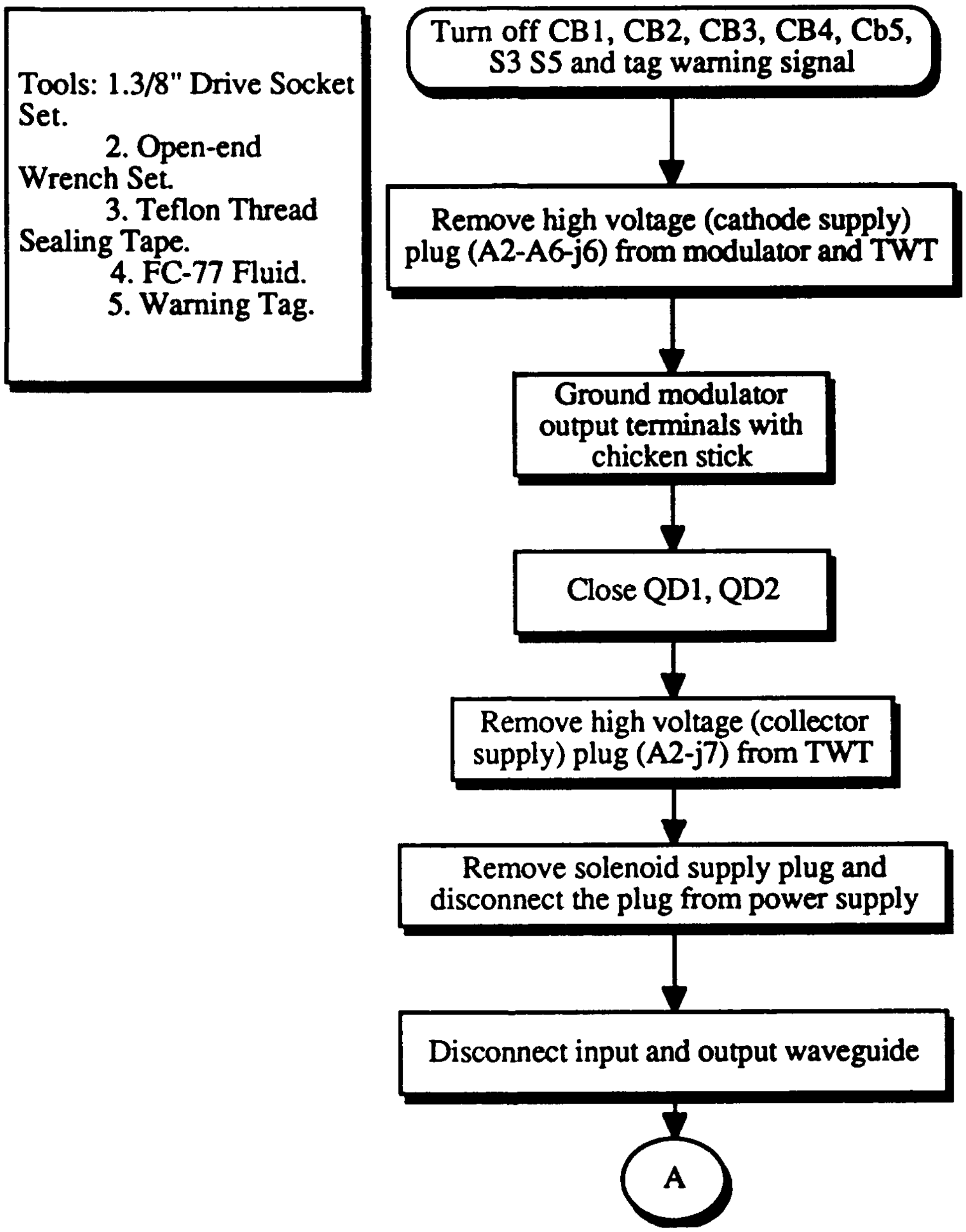

Figure A.6 High Power TWT Removal and Replacement Maintenance Flowchart

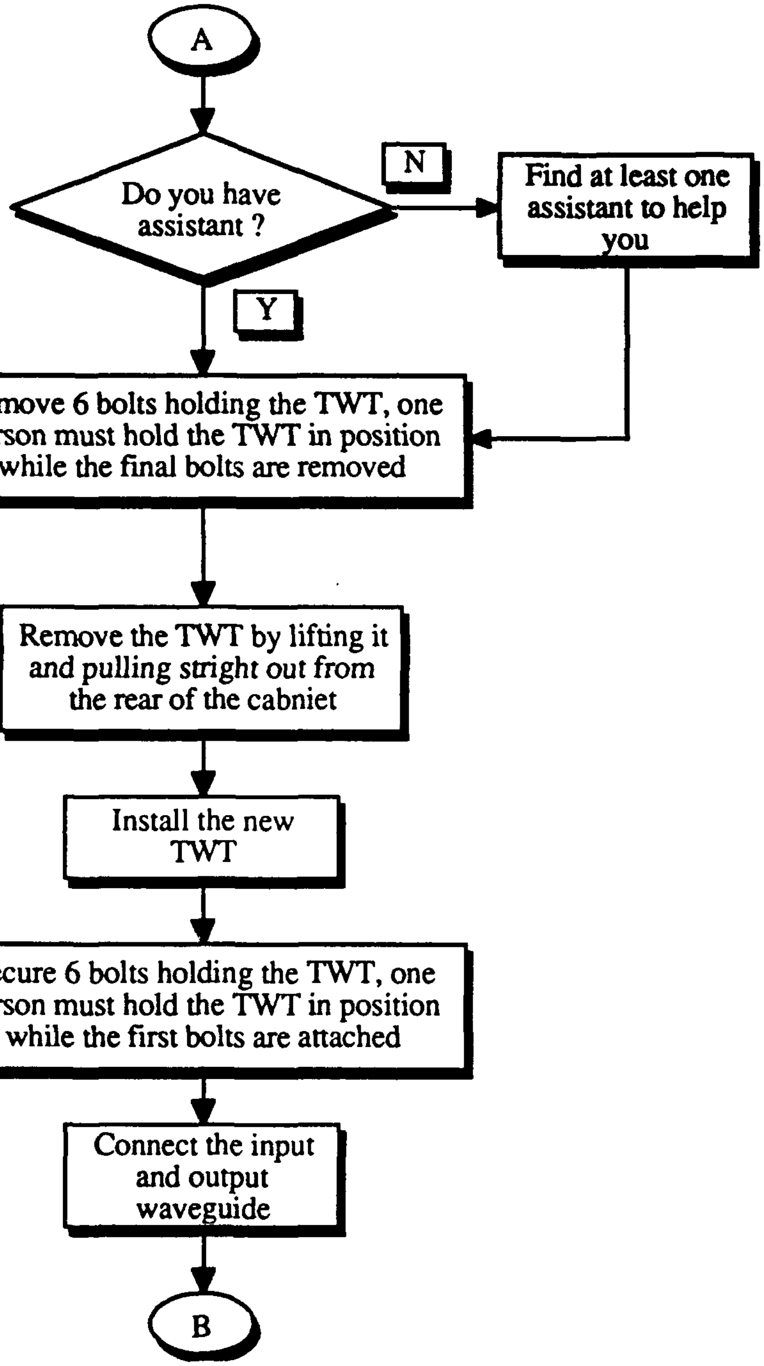

Figure A.6 High Power TWT Removal and Replacement Maintenance Flowchart (continued)

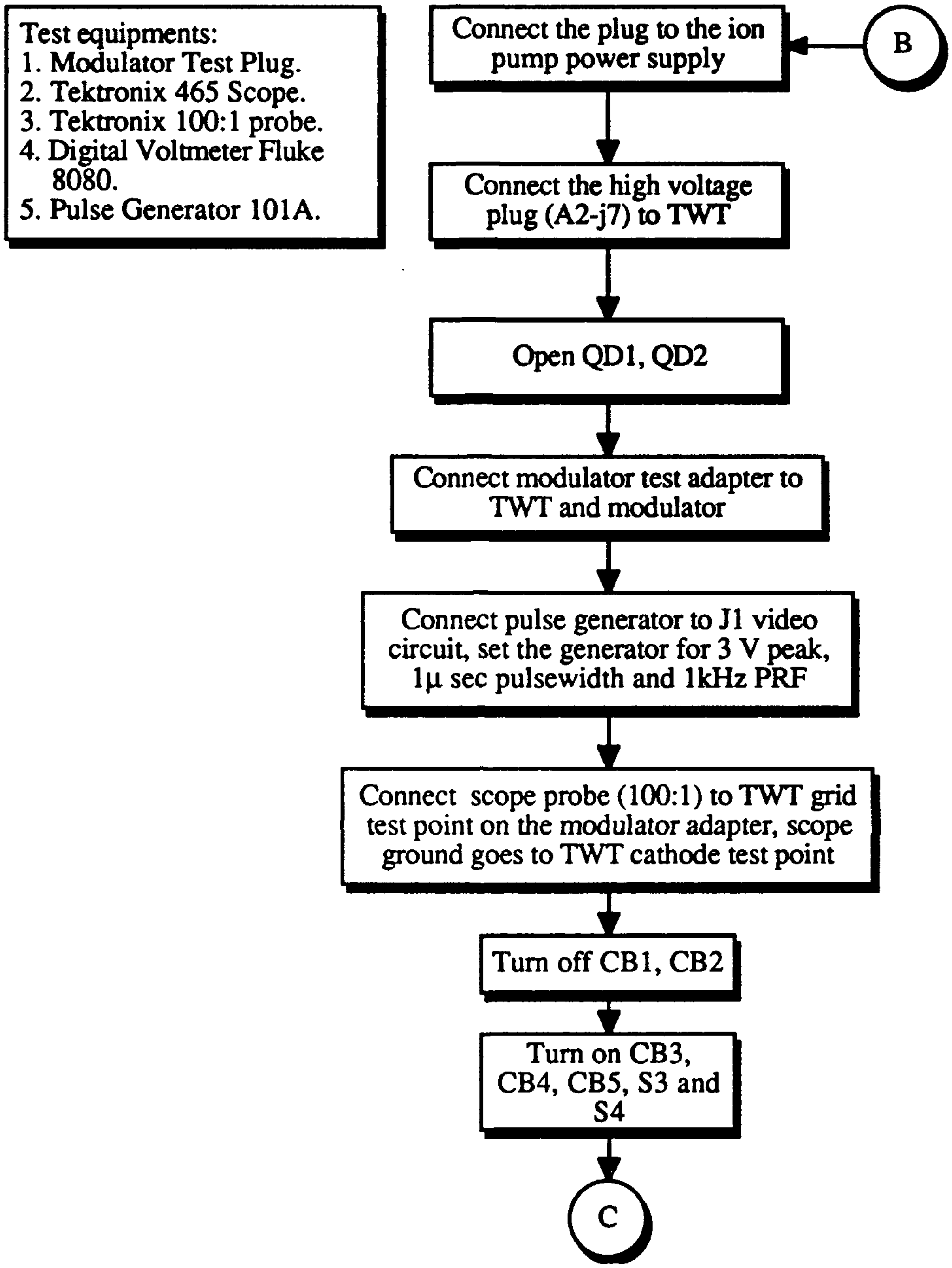

Figure A.6 High Power TWT Removal and Replacement Maintenance Flowchart (continued)

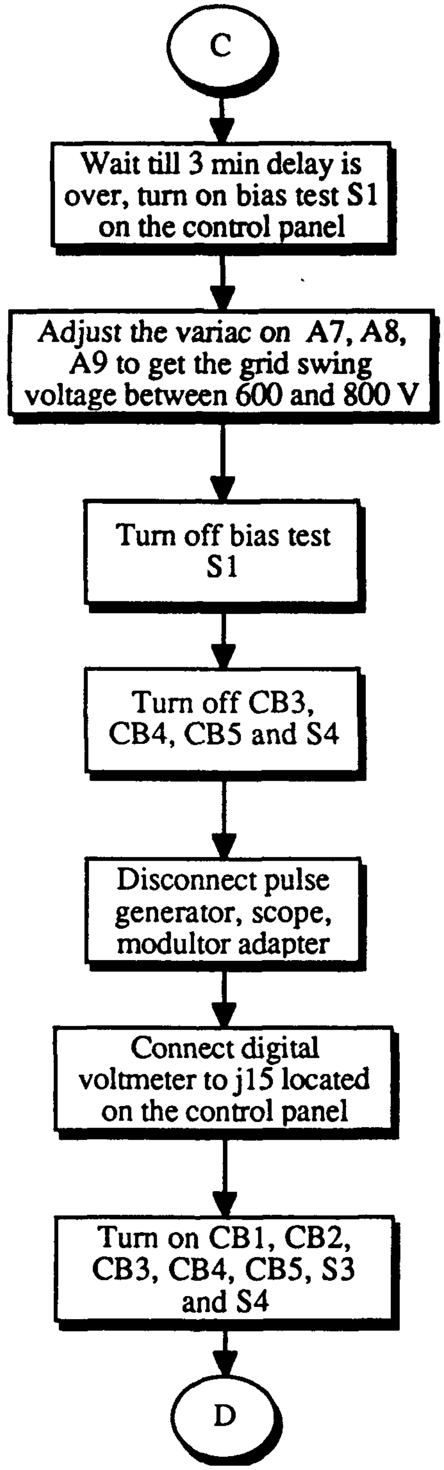

Figure A.6 High Power TWT Removal and Replacement Maintenance Flowchart (continued)

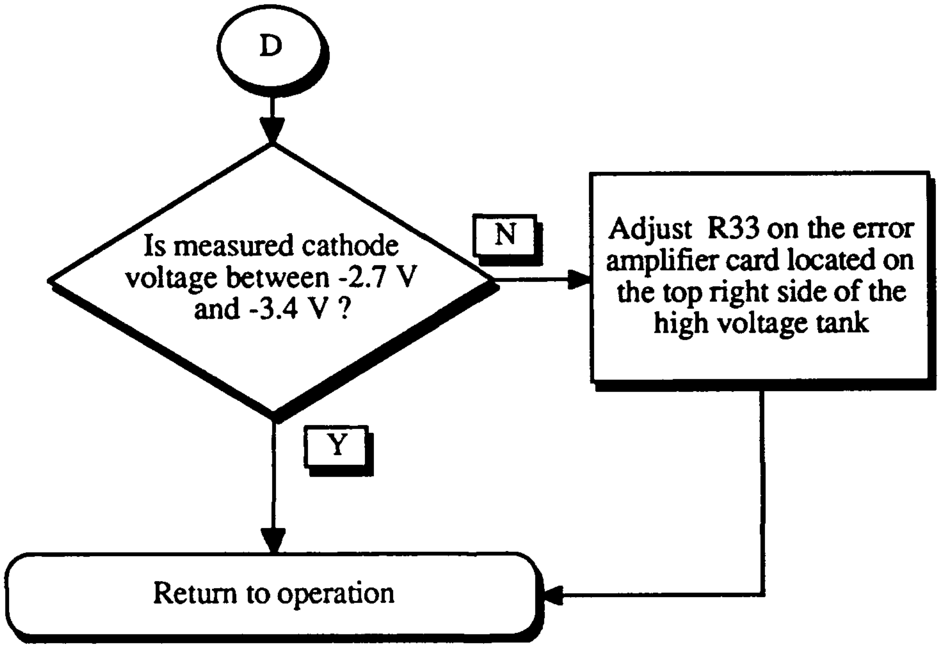

Figure A.6 High Power TWT Removal and Replacement Maintenance Flowchart (continued)

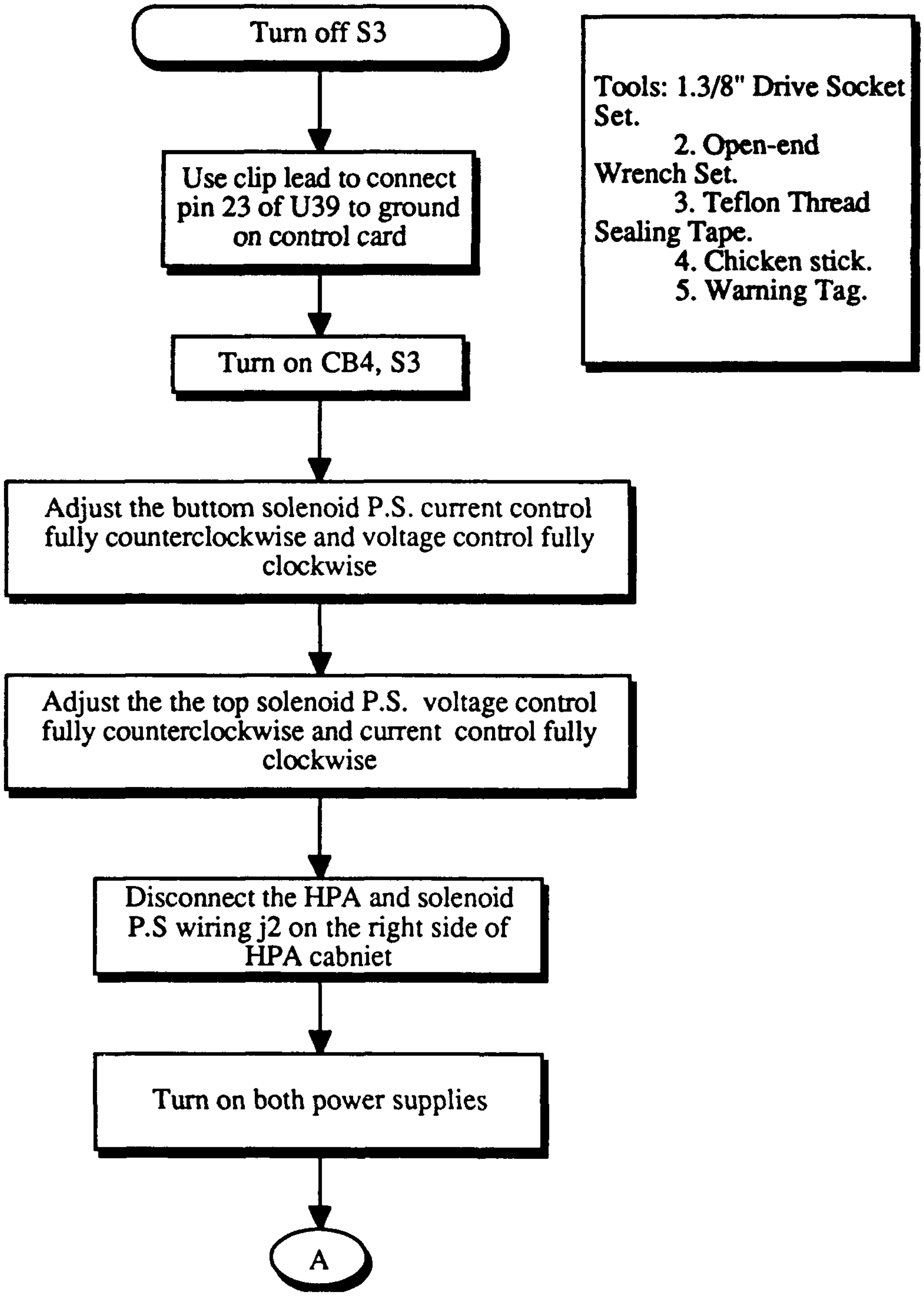

Figure A.7 Solenoid Power Supply Alignment Maintenance Flowchart

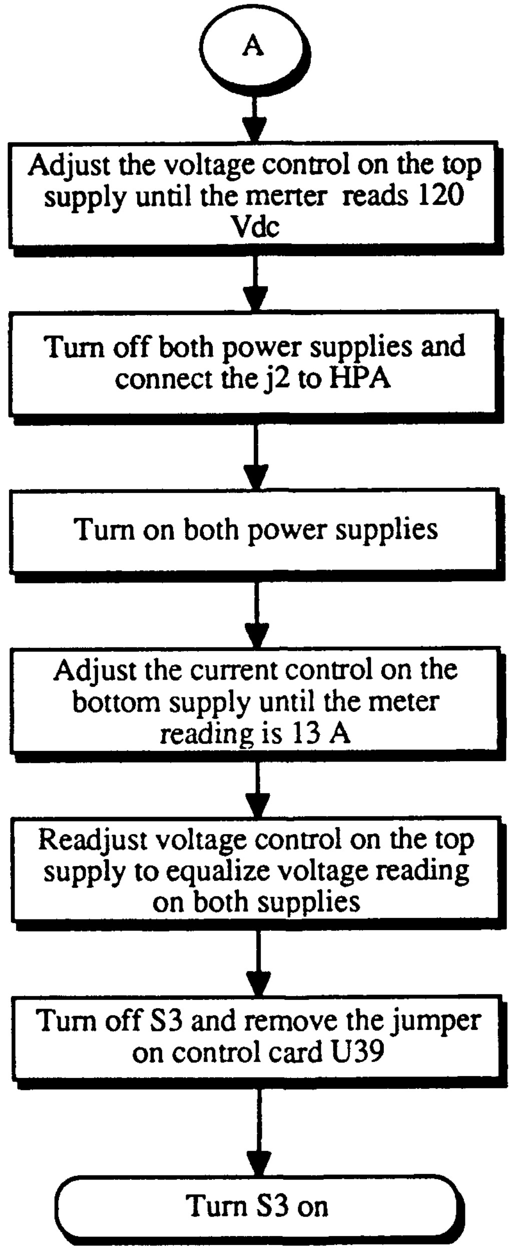

Figure A.7 Solenoid Power Supply Alignment Maintenance Flowchart (continued)

APPENDIX B SYSTEM TROUBLESHOOTING FLOWCHARTS

Fault Indicator	Flowchart Figure
HPA Fault	B.1
Coolant Level	B.2
Ion P.S. Undervoltage	B.3
TWT Ion Overcurrent	B.4
High VSWR	B.5
Negative Bias Vlotage	B.6
Positive Bias Voltage	B.7
Filament Voltage	B.8
Solenoid Power	B.9
TWT Arc	B.10
Coolant (FC-77) Flow	B.11
Coolant Overtemperature	B.12
440 Vac	B.13
Circuit Breaker Open	B.14
Body Overcurrent	B.15
TWT Overduty	B.16
Collector Voltage	B.17
Body Voltage	B.18
High Voltage Short	B.19
Modulator	B.20

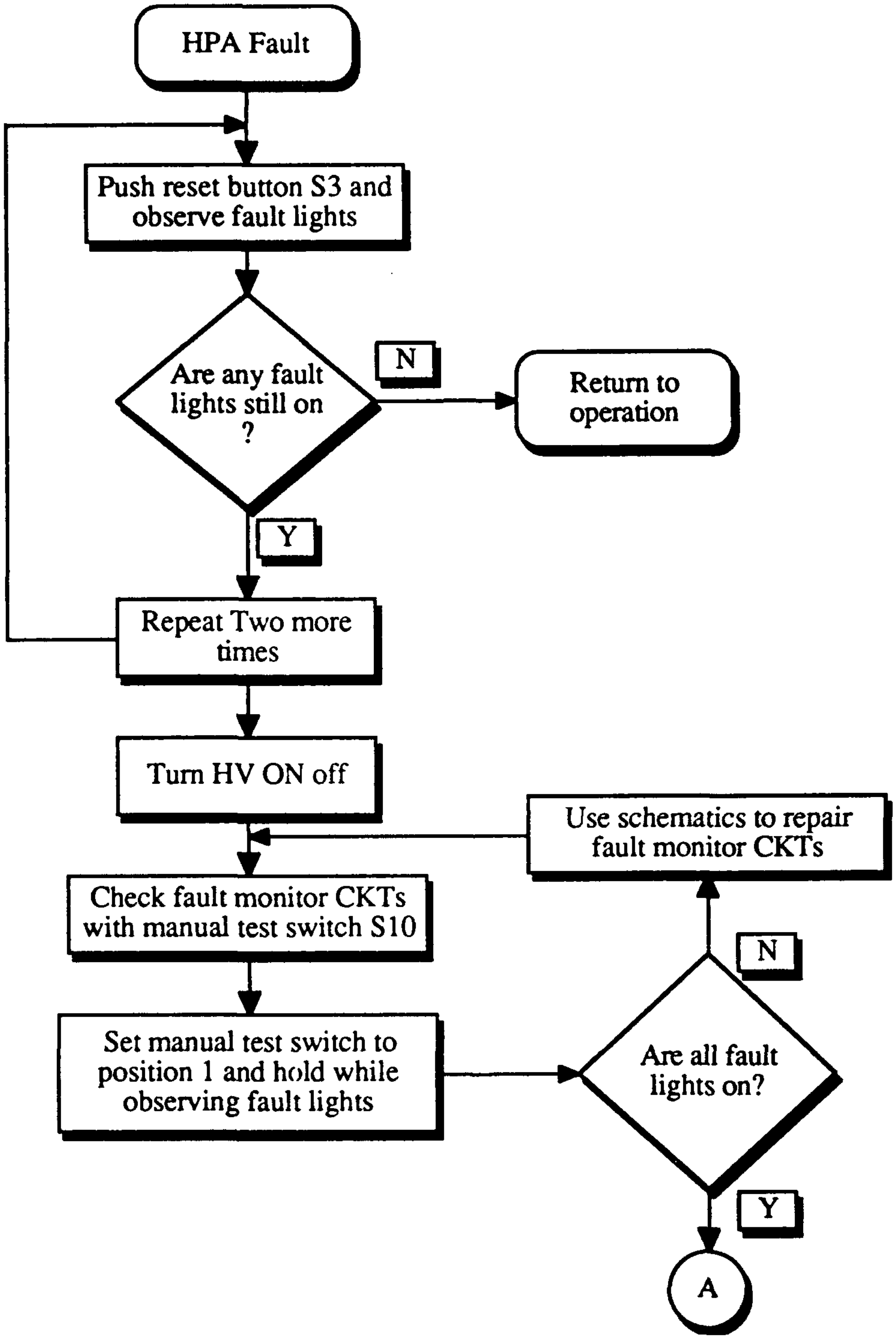

Figure B.1 HPA Troubleshooting Flowchart

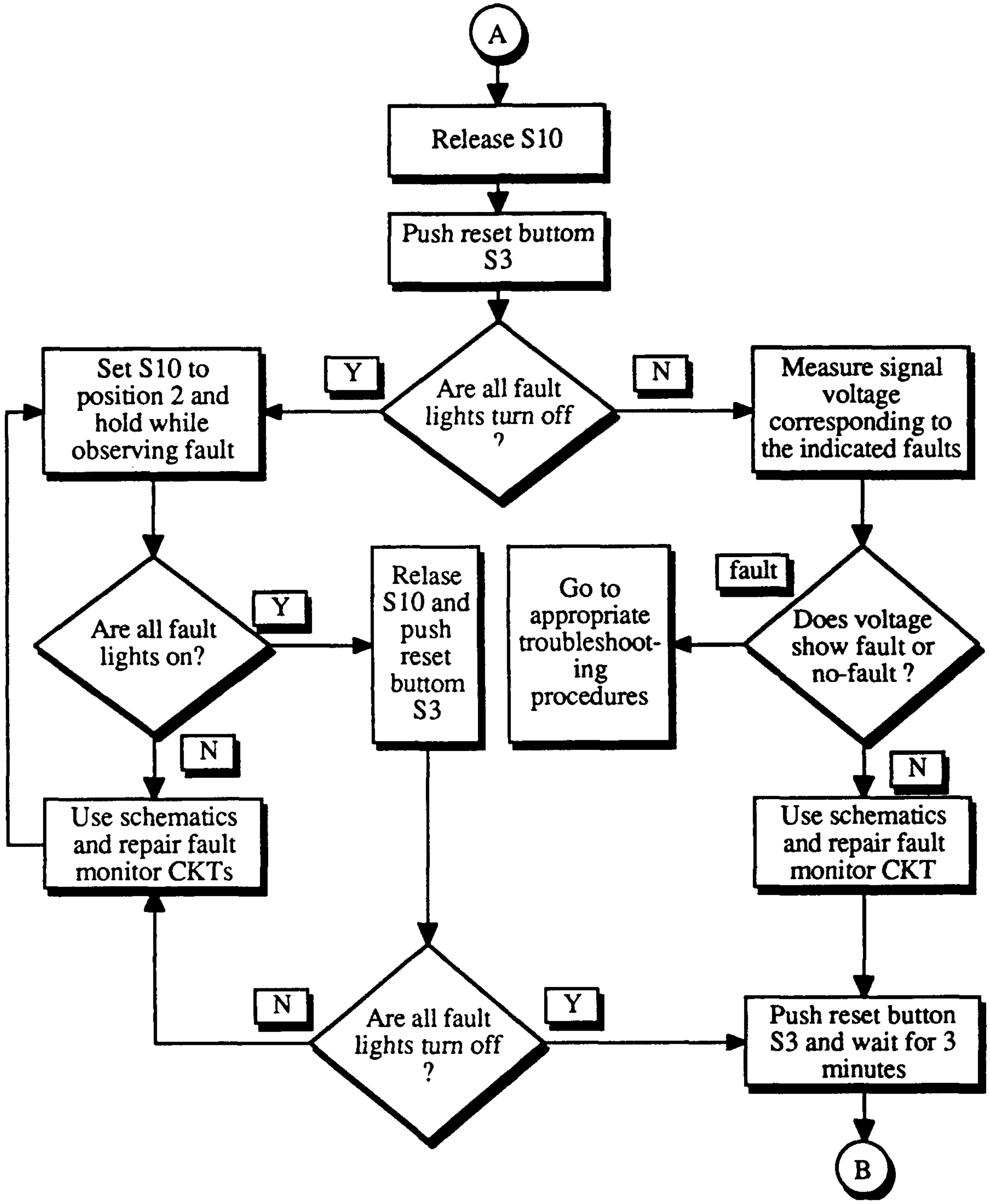

Figure B.1 HPA Troubleshooting Flowchart (continued)

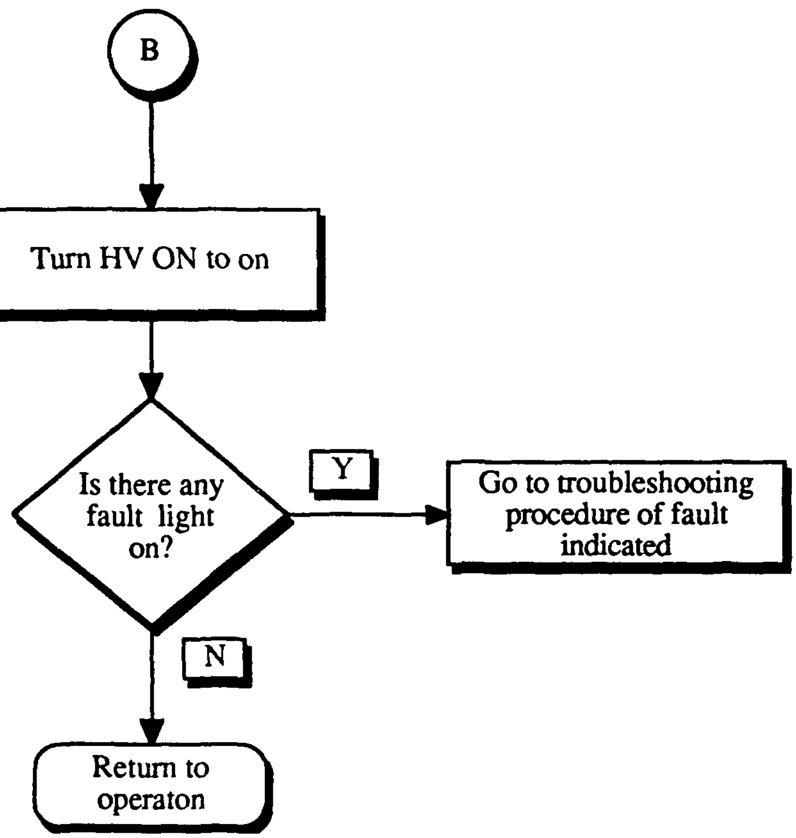

Figure B.1 HPA Troubleshooting Flowchart (continued)

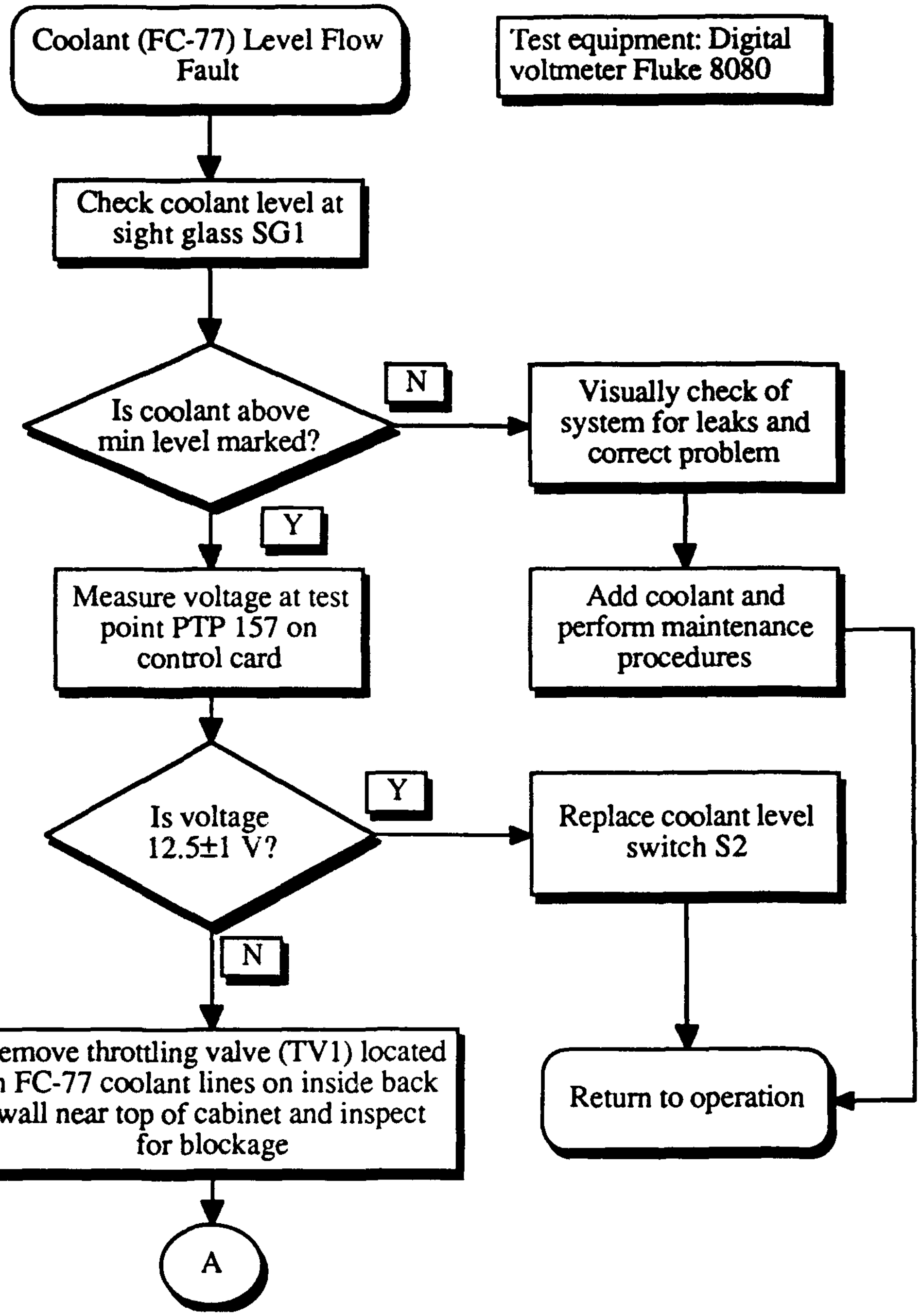

Figure B.2 Coolant (FC-77) Level Fault Troubleshooting Flowchart

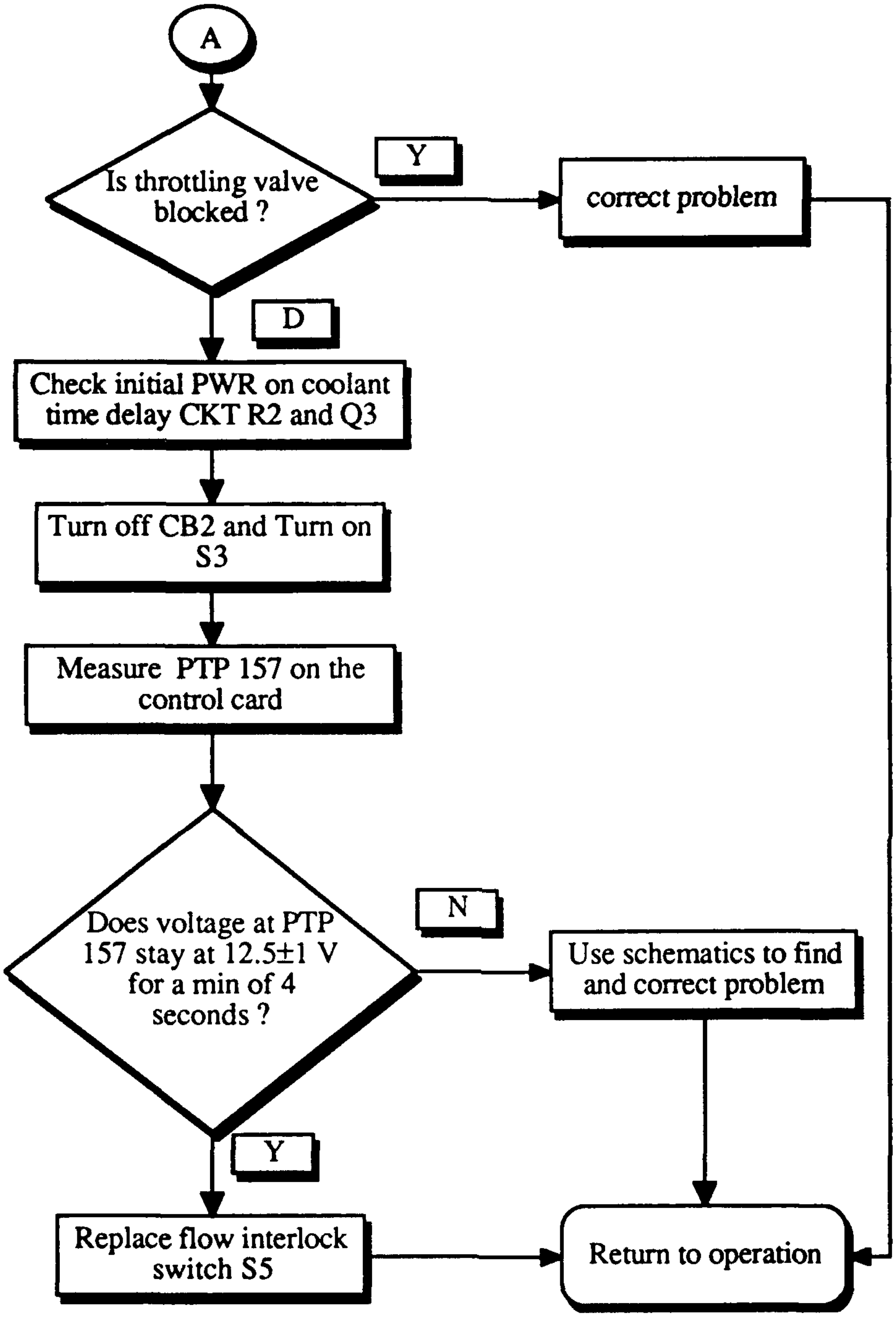

Figure B.2 Coolant (FC-77) Level Fault Troubleshooting Flowchart (continued)

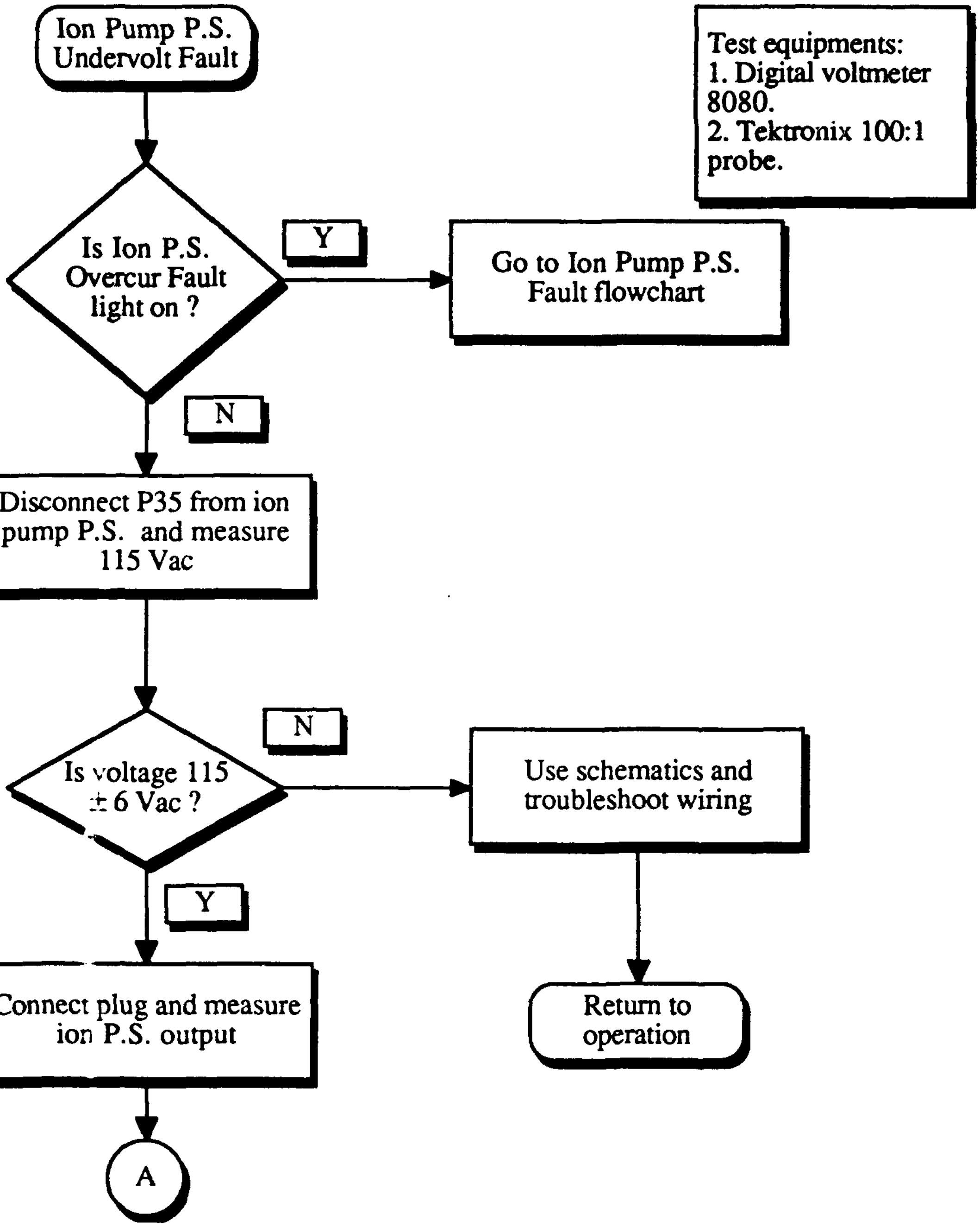

Figure B.3 Ion Pump Power Supply Undervoltage Fault Troubleshooting Flowchart

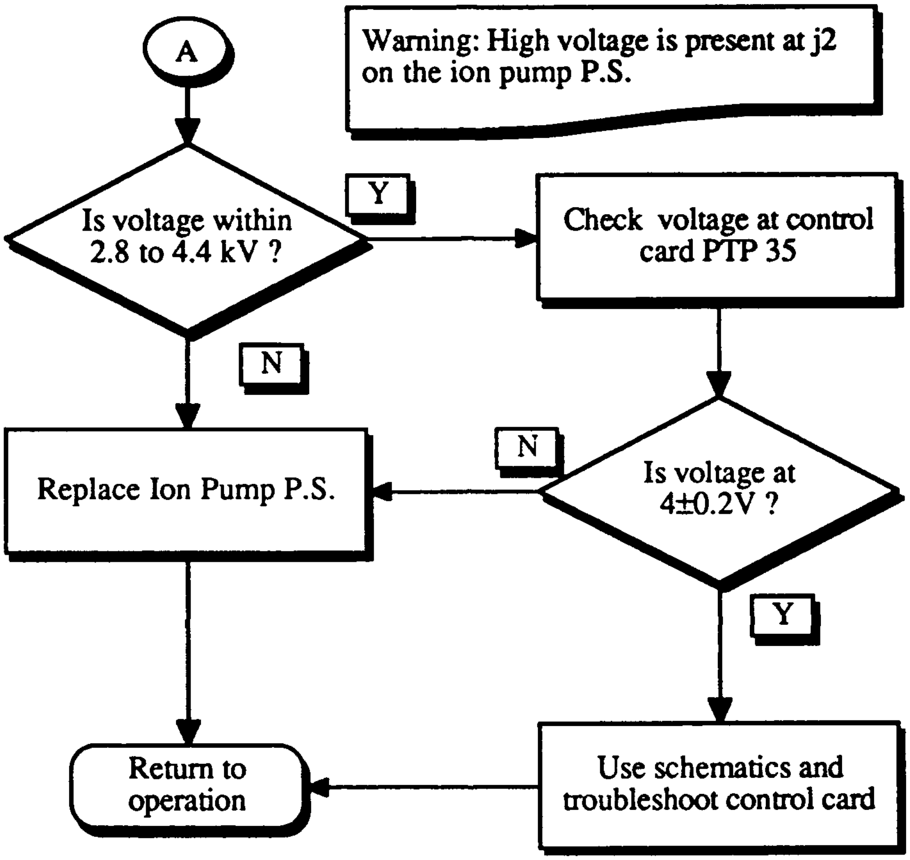

Figure B.3 Ion Pump Power Supply Undervoltage Fault Troubleshooting Flowchart (continued)

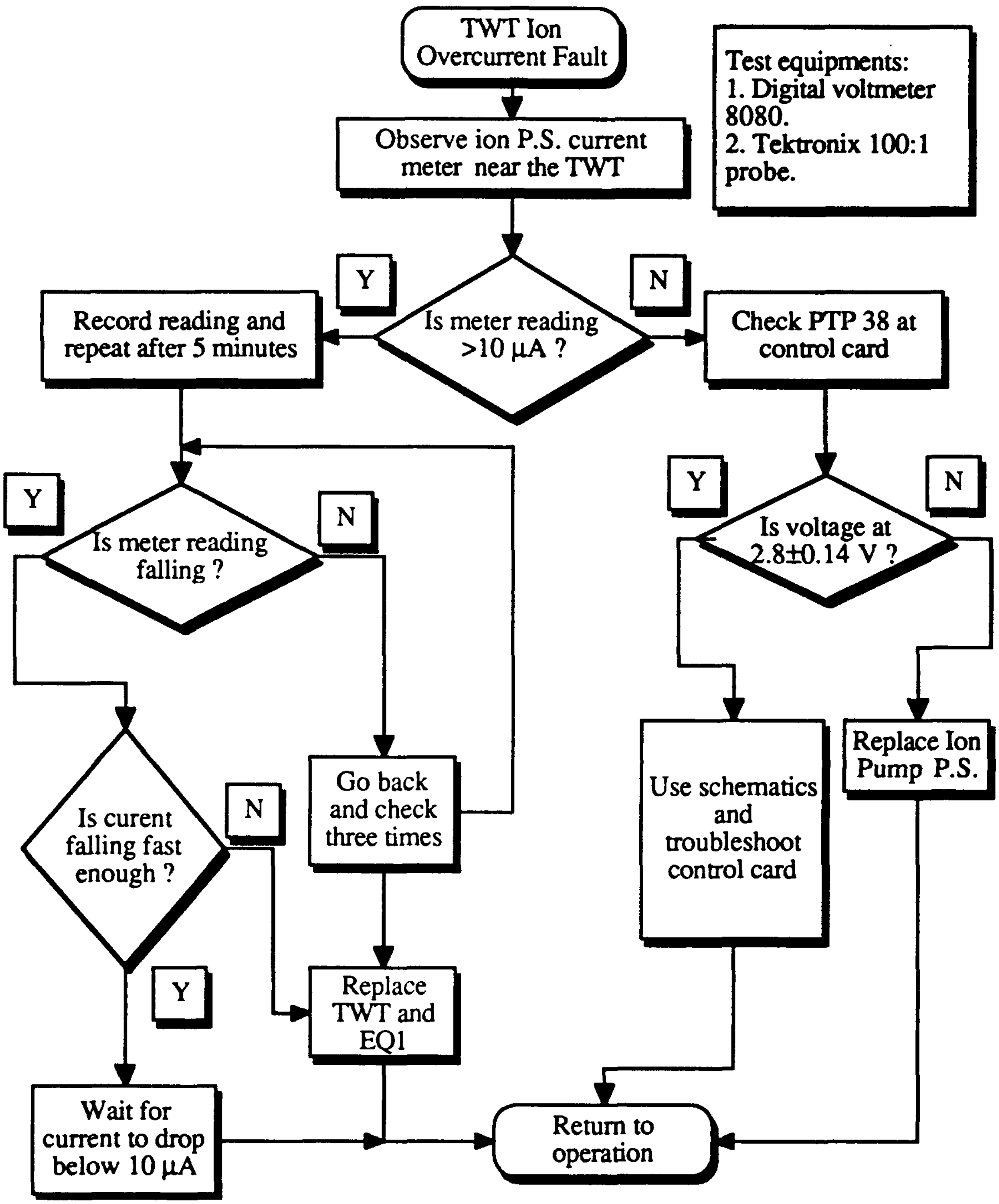

Figure B.4 TWT Ion Overcurrent Fault Troubleshooting Flowchart

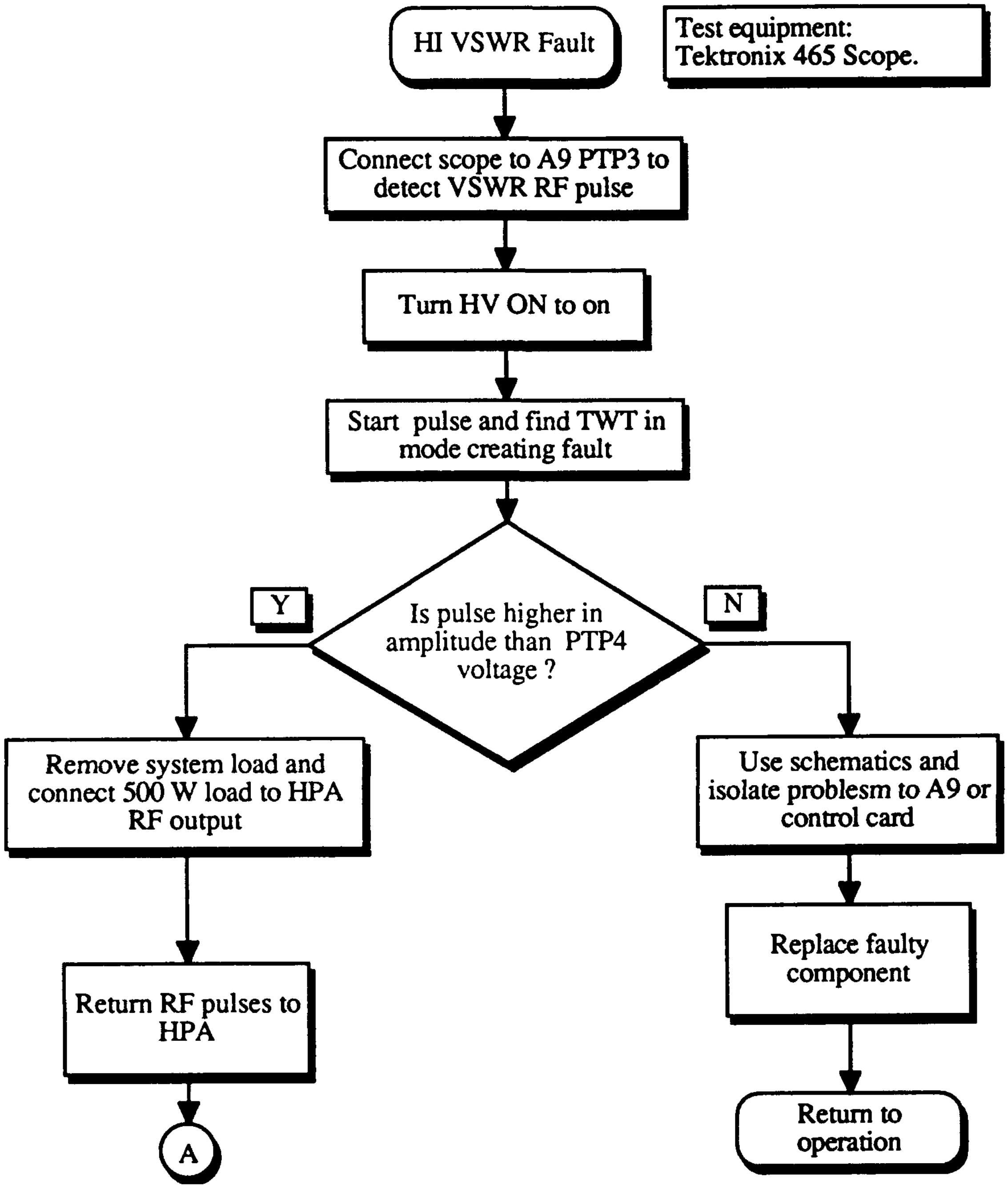

Figure B.5 High VSWR Fault Troubleshooting Flowchart

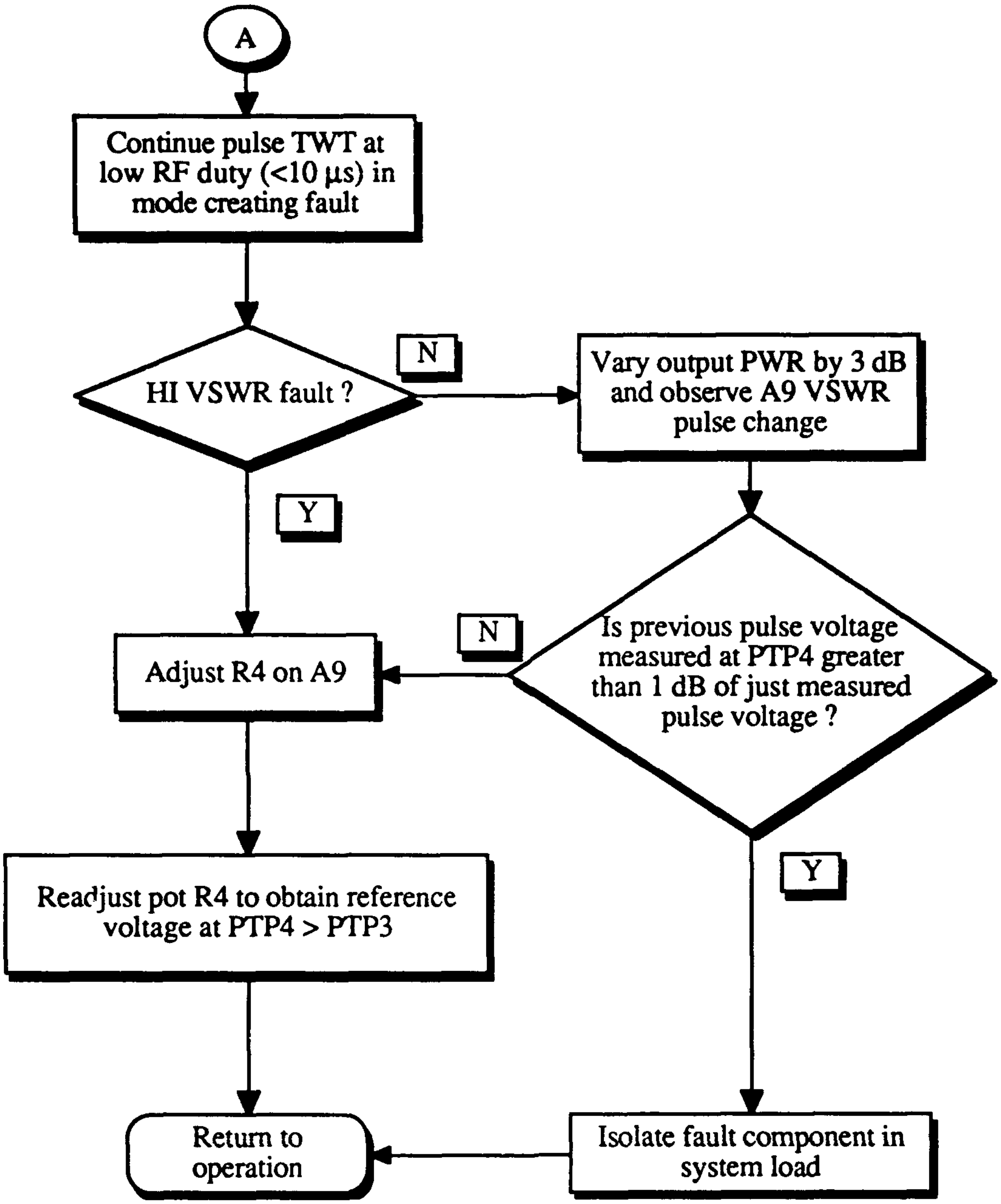

Figure B.5 High VSWR Fault Troubleshooting Flowchart (continued)

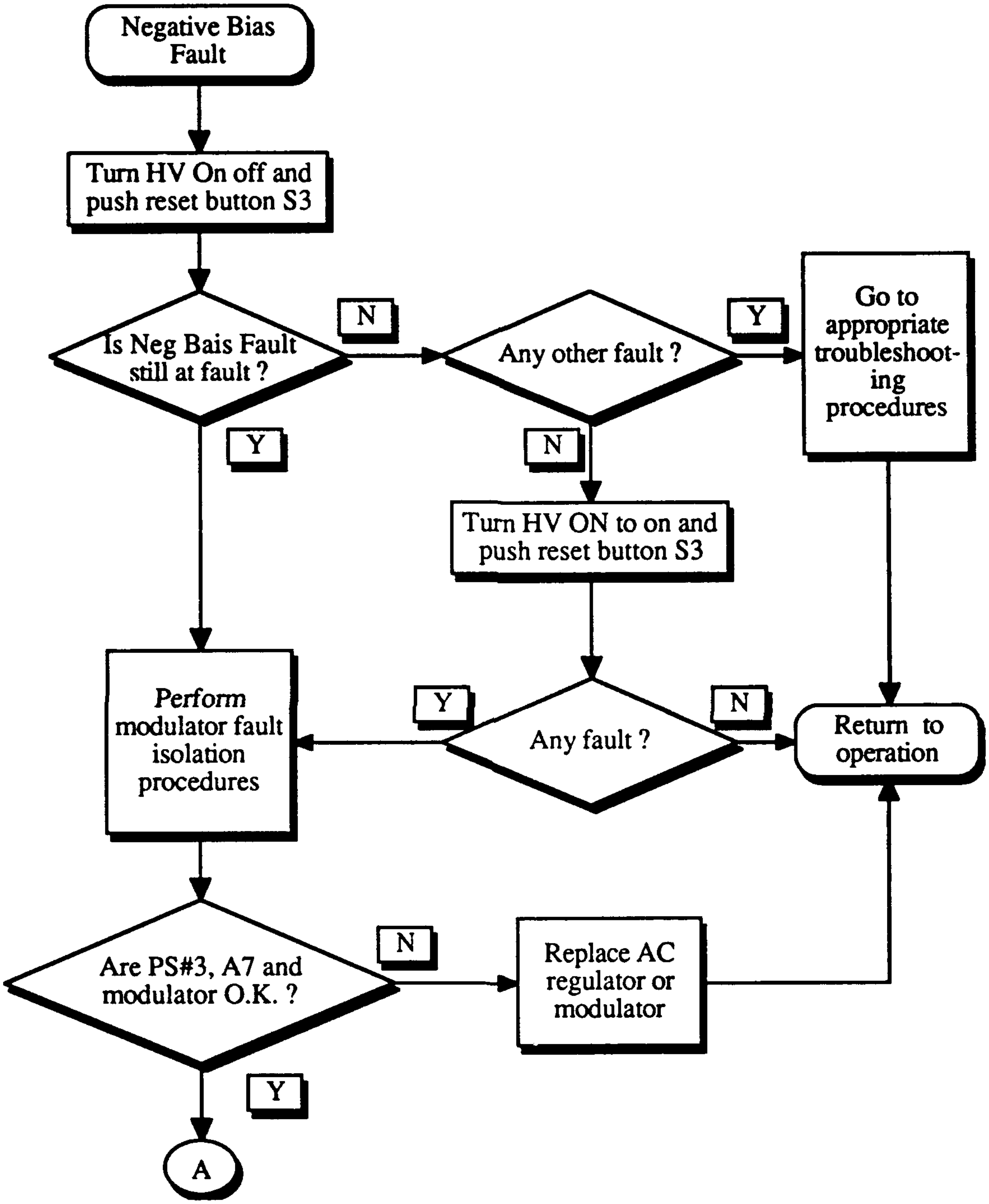

Figure B.6 Negative Bias Voltage Fault Troubleshooting Flowchart

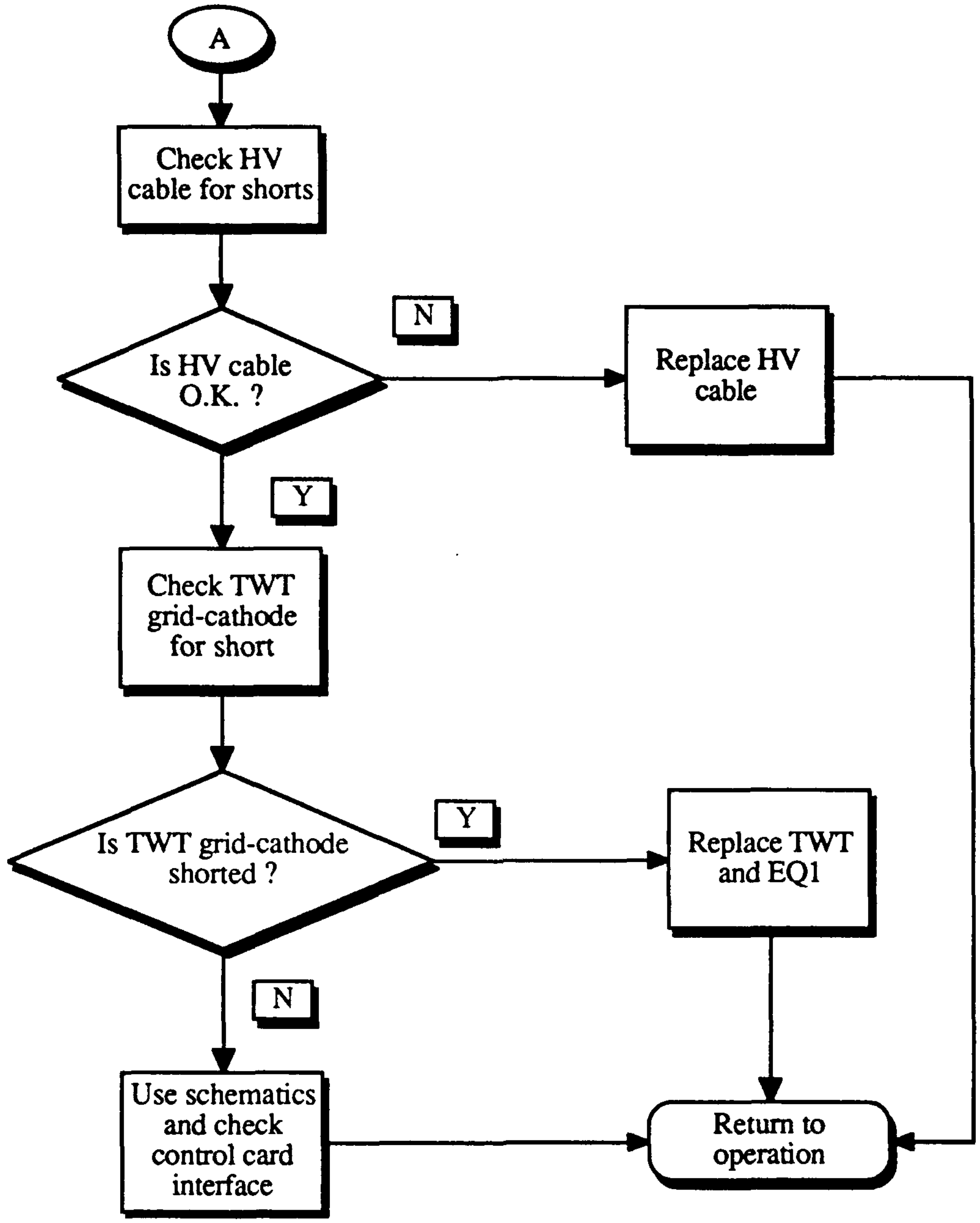

Figure B.6 Negative Bias Voltage Fault Troubleshooting Flowchart (continued)

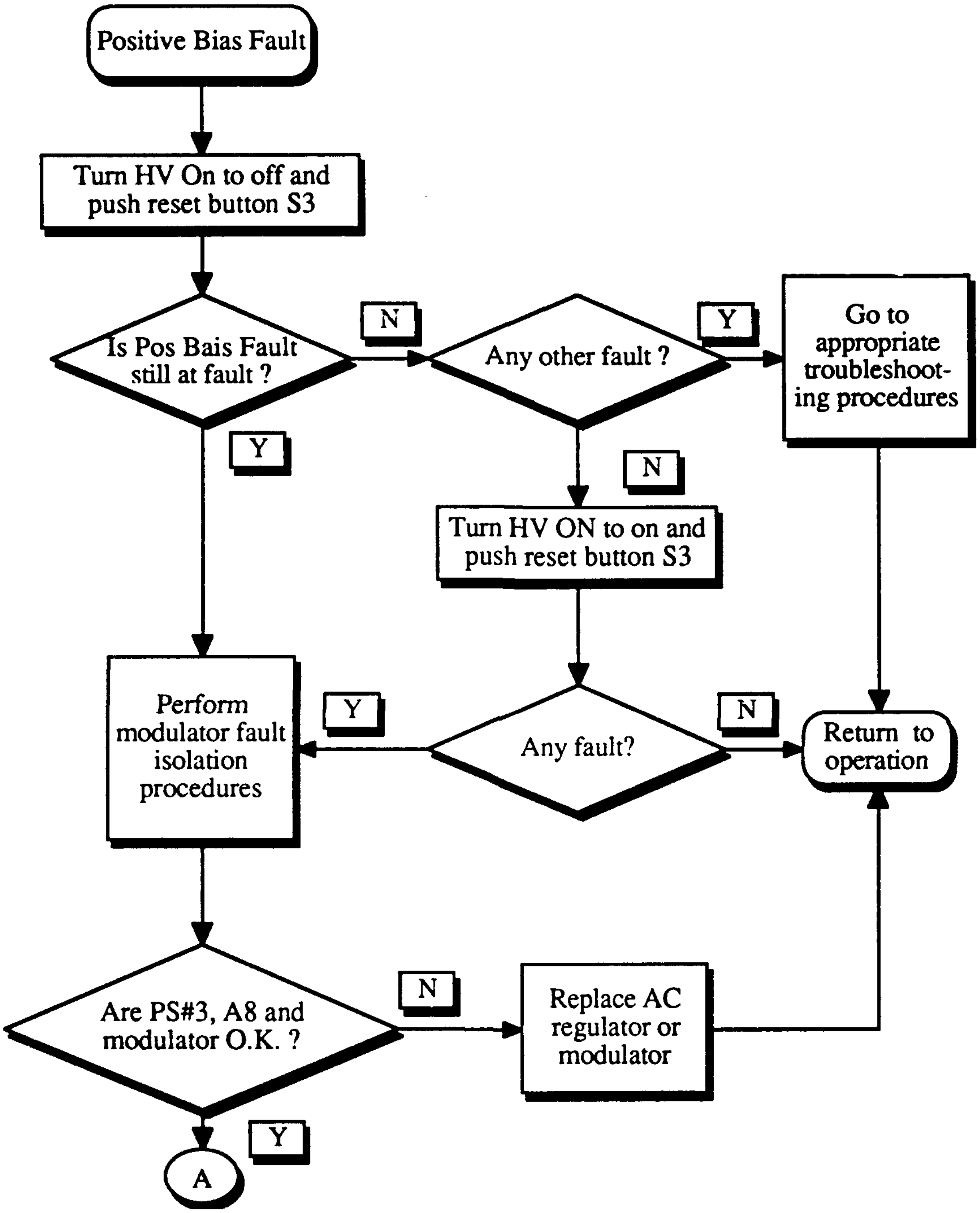

Figure B.7 Positive Voltage Fault Troubleshooting Flowchart

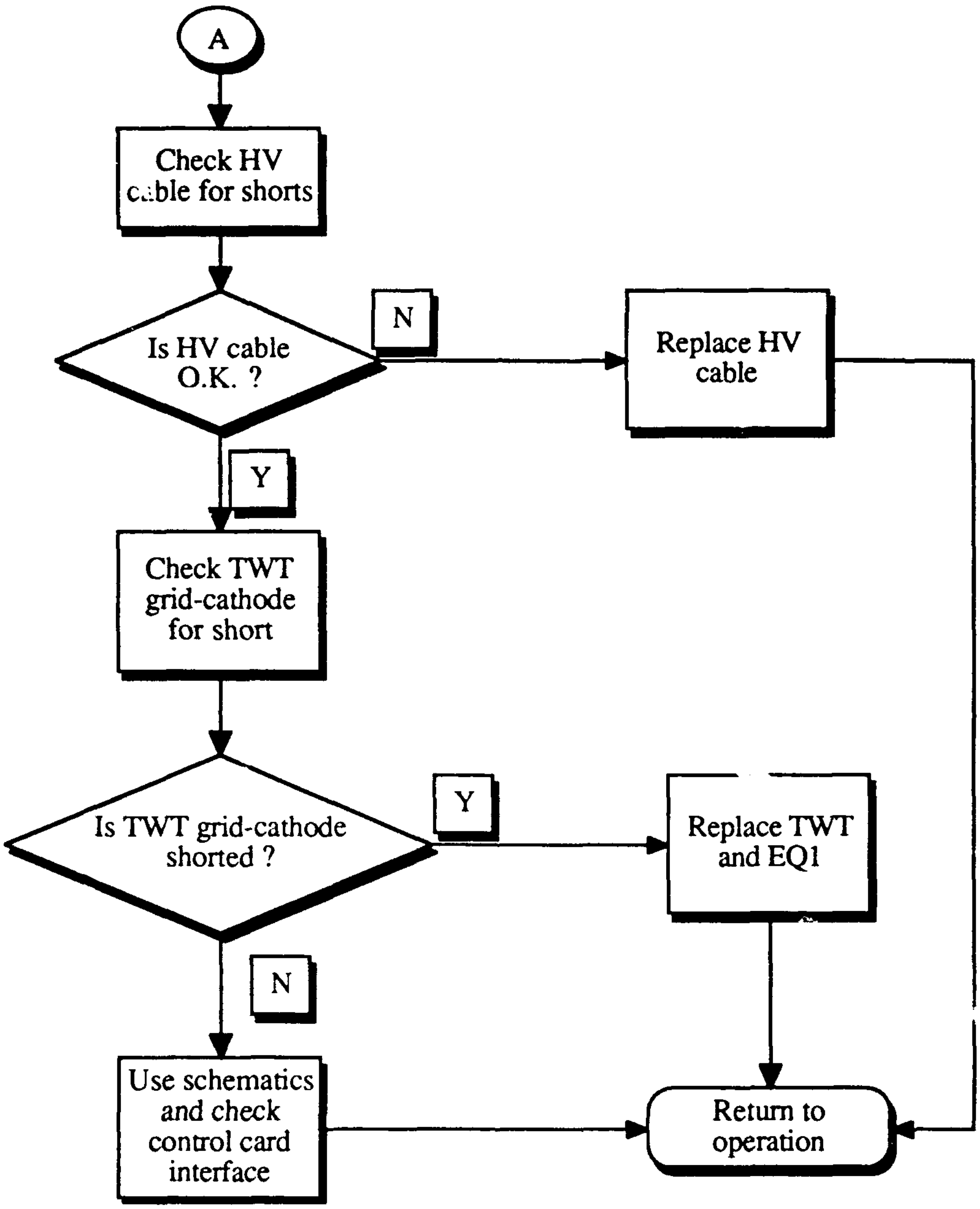

Figure B.7 Positive Voltage Fault Troubleshooting Flowchart (continued)

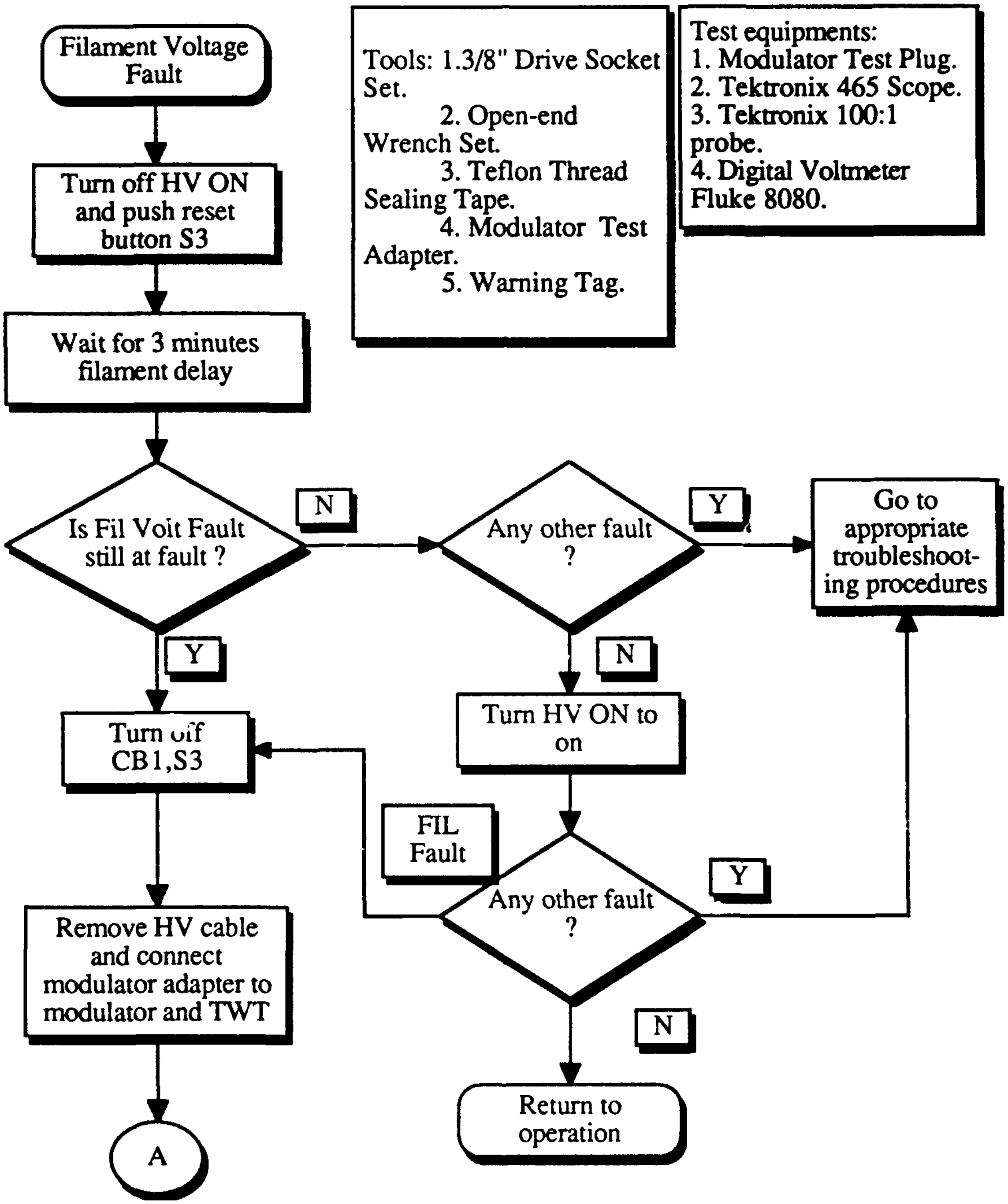

Figure B.8 Filament Voltage Regulator Fault Troubleshooting Flowchart

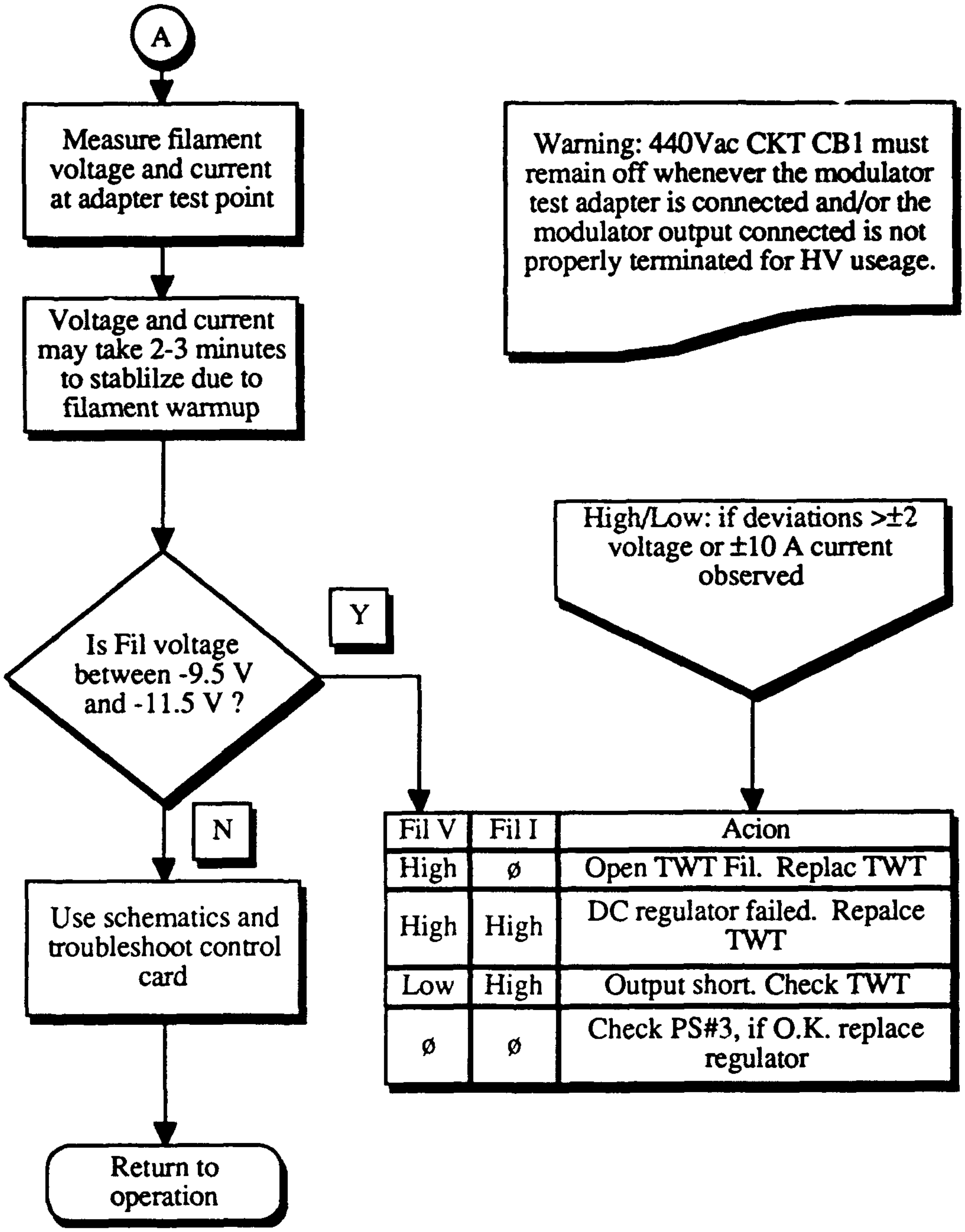

Figure B.8 Filament Voltage Regulator Fault Troubleshooting Flowchart (continued)

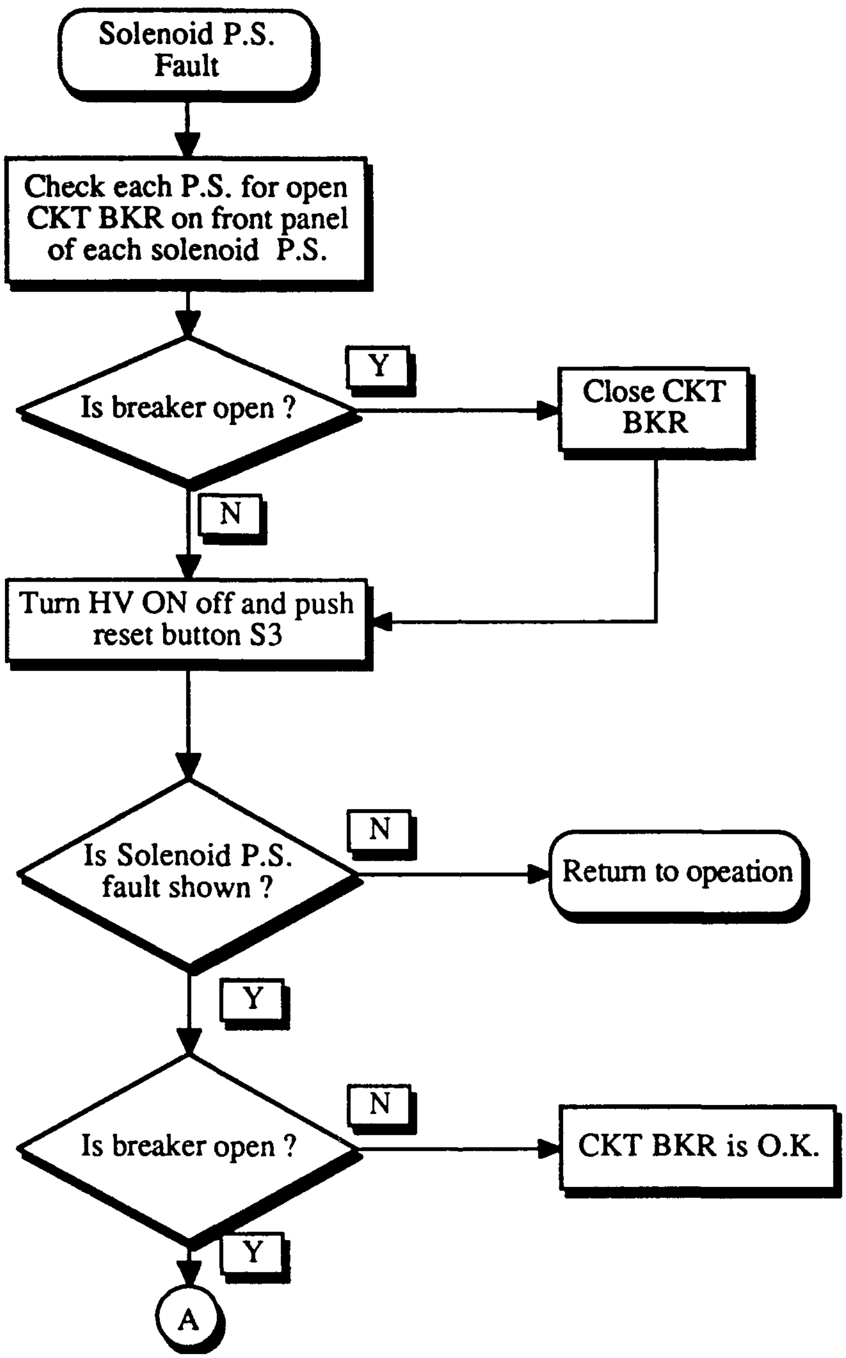

Figure B.9 Solenoid Power Supply Troubleshooting Flowchart

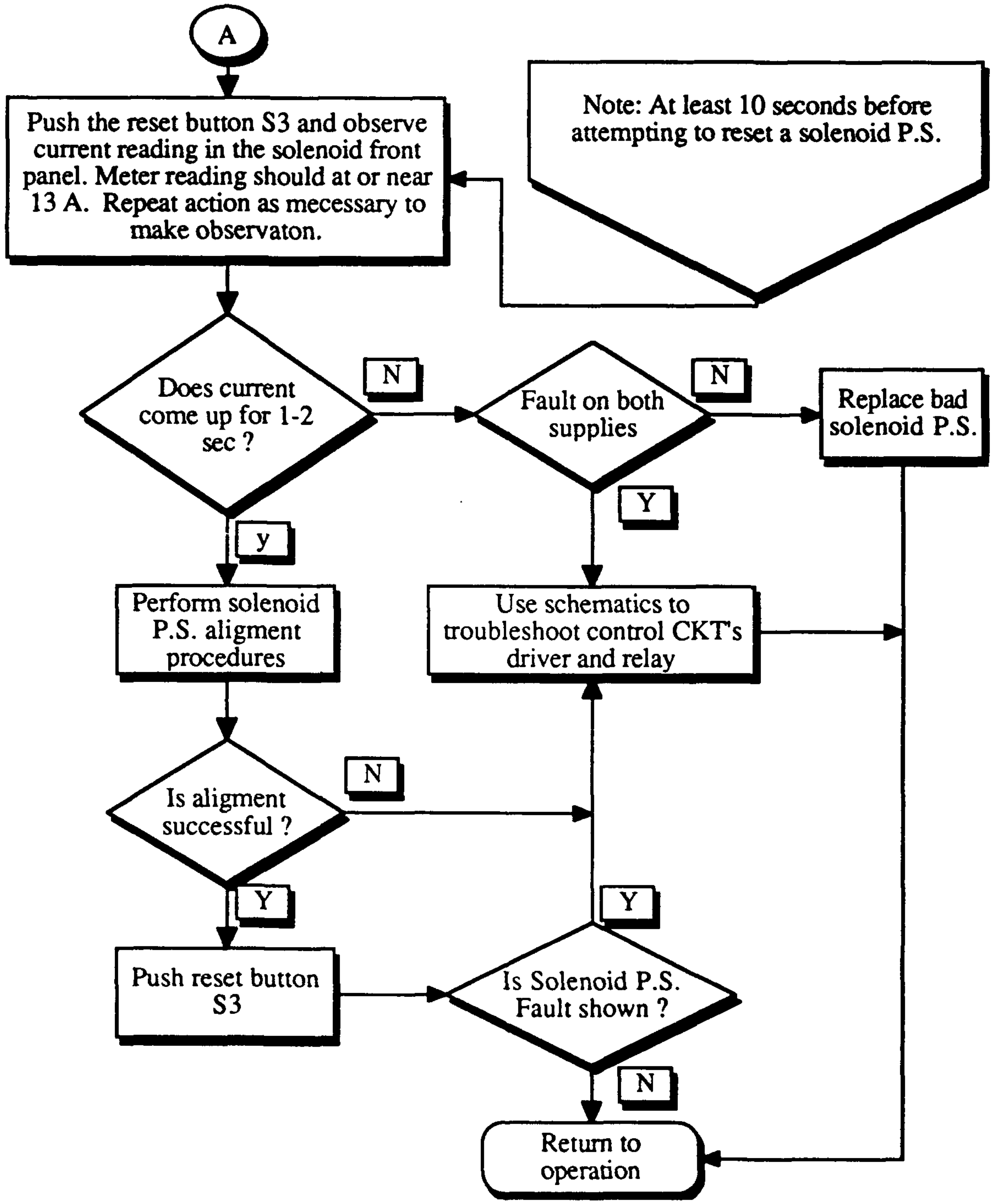

Figure B.9 Solenoid Power Supply Troubleshooting Flowchart (continued)

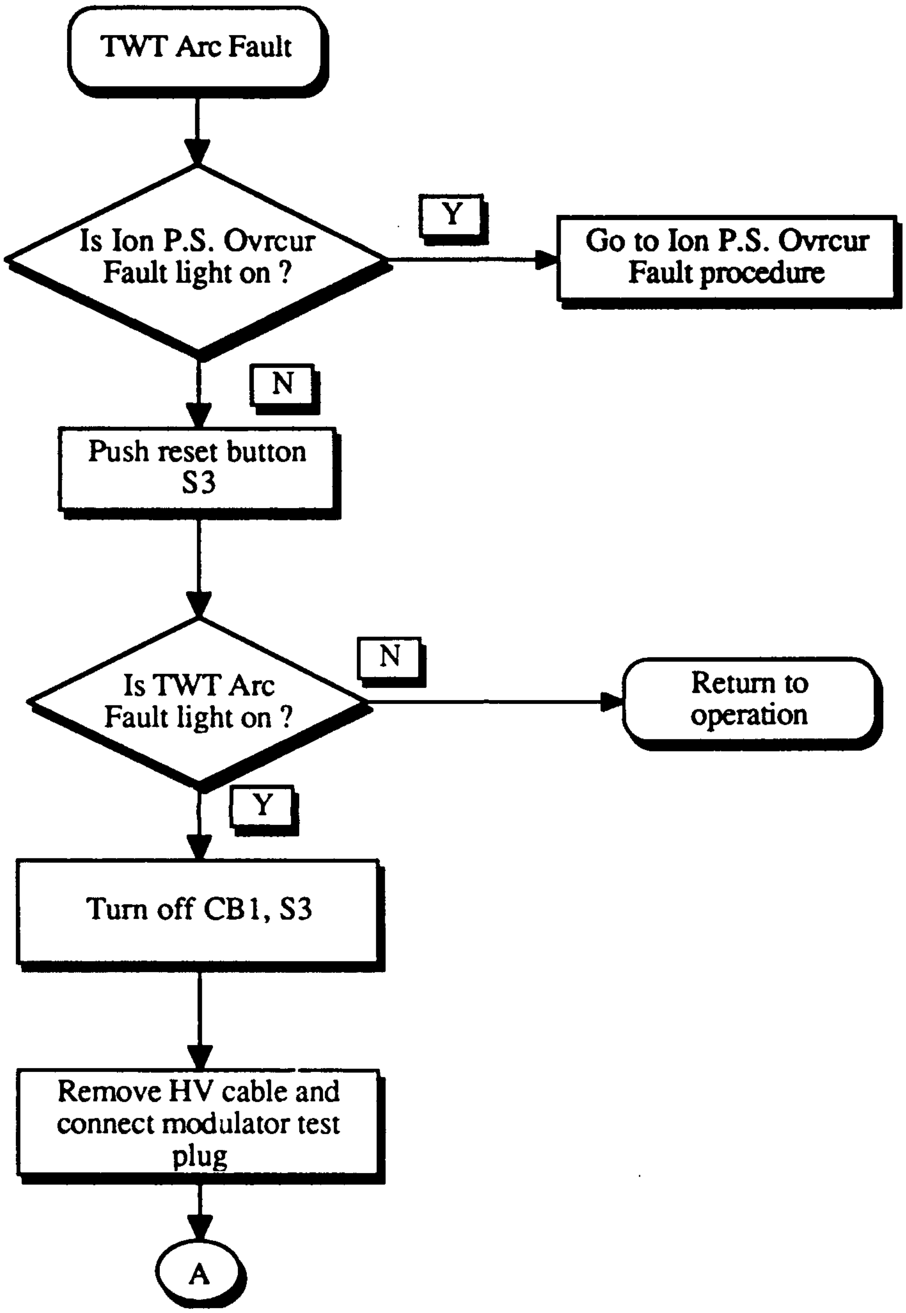

Figure A.10 TWT Arc Fault Troubleshooting Flowchart

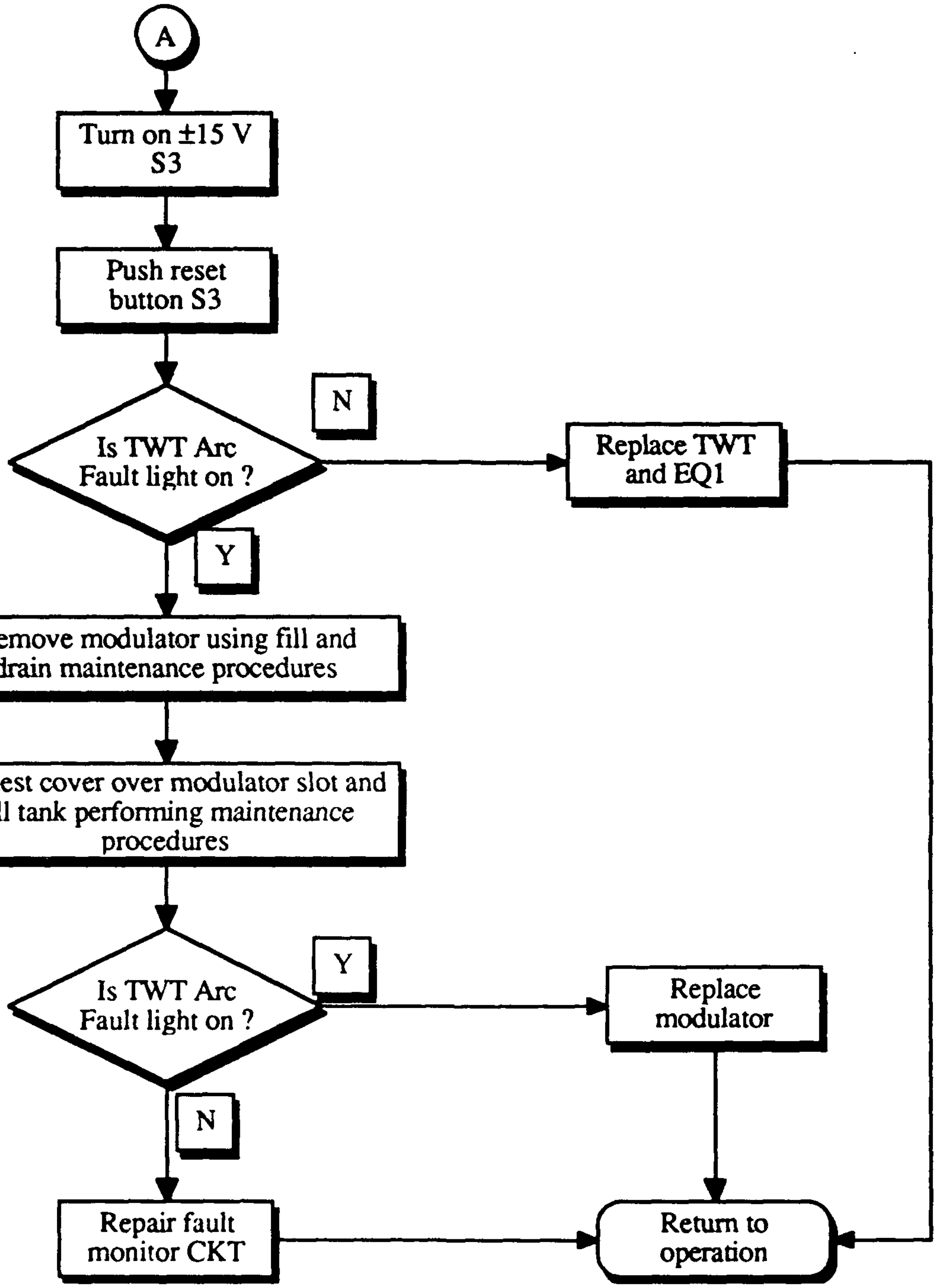

Figure A.10 TWT Arc Fault Troubleshooting Flowchart (continued)

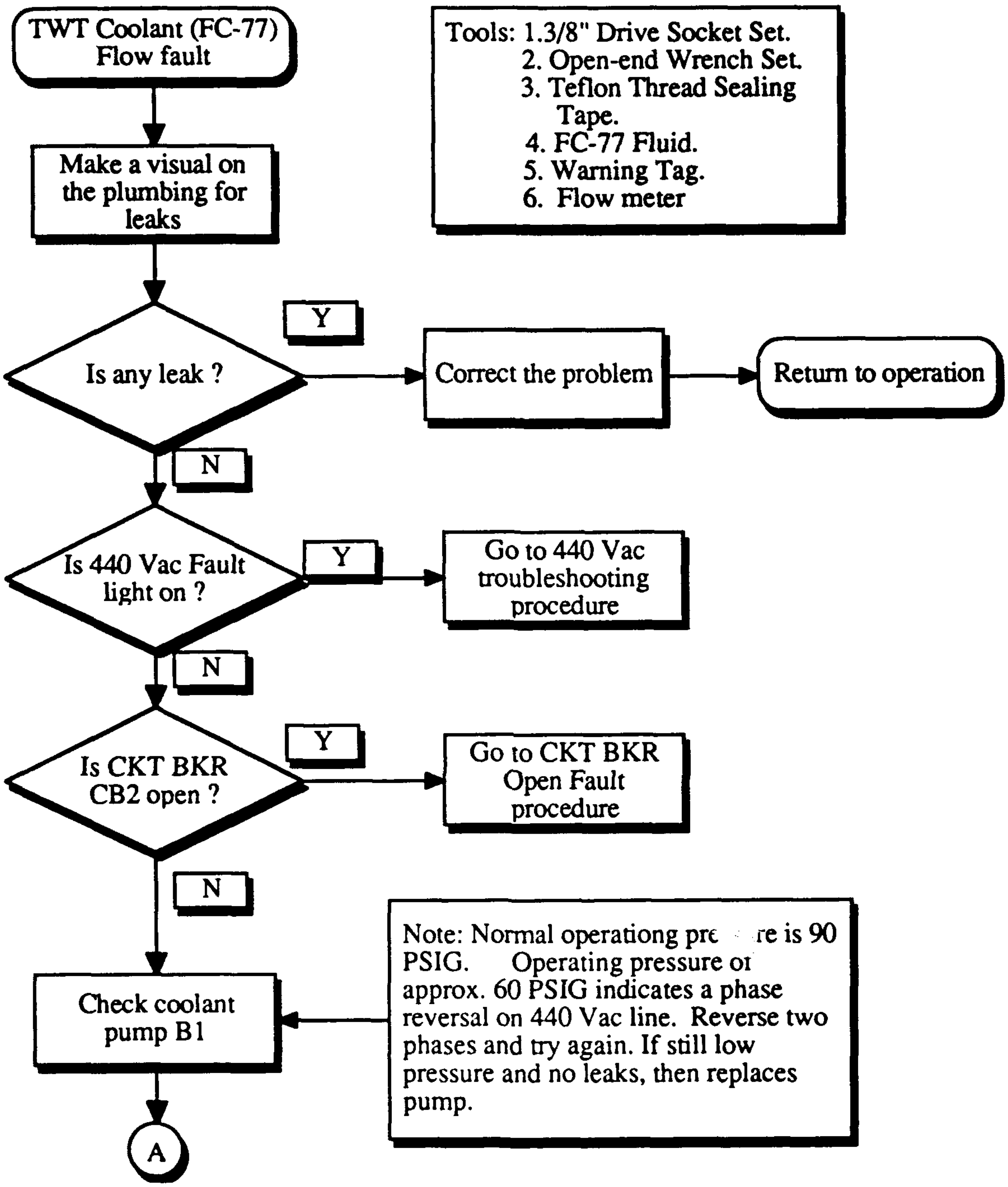

Figure A.11 Coolant (FC-77) Flow Fault Troubleshooting Flowchart

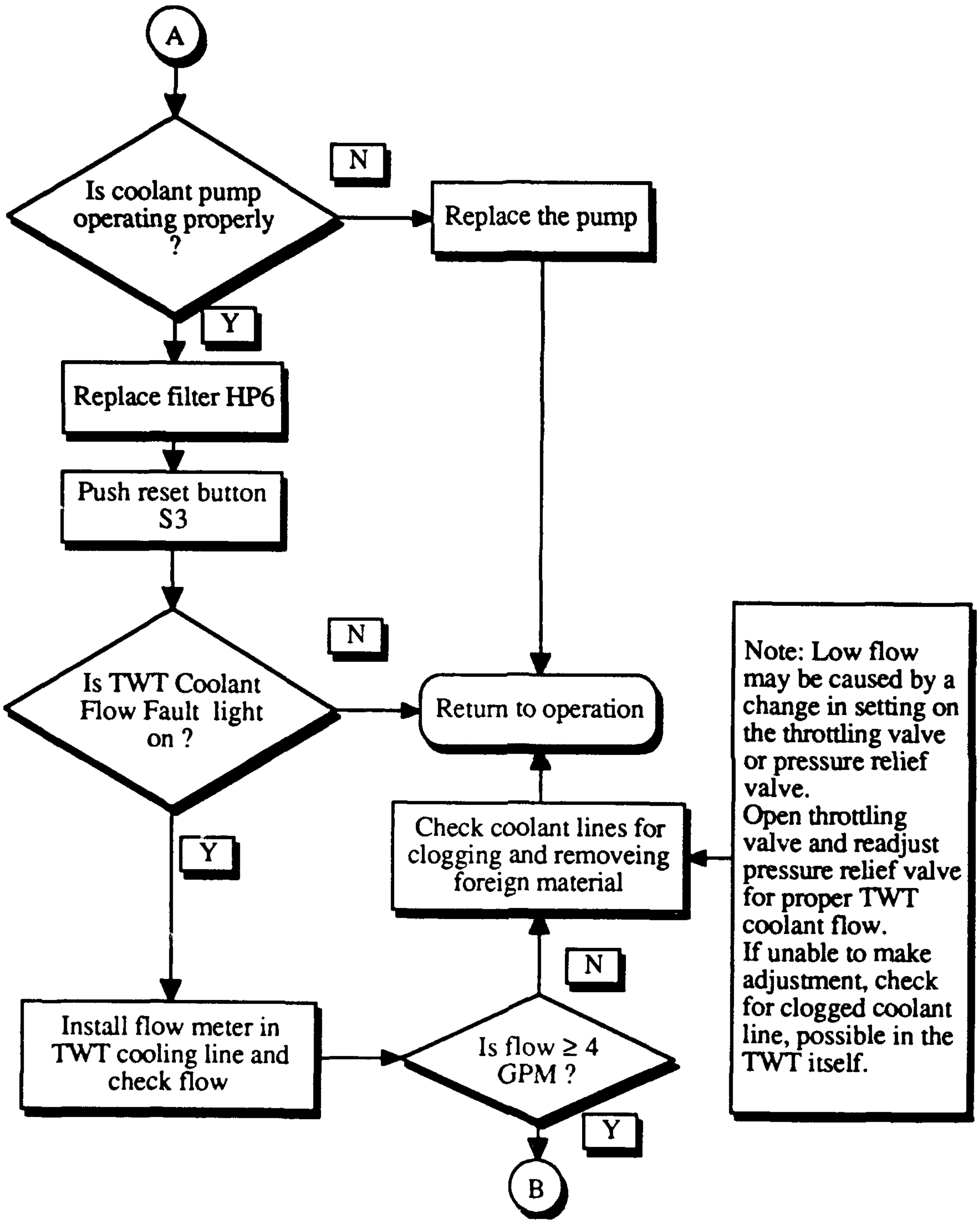

Figure A.11 Coolant (FC-77) Flow Fault Troubleshooting Flowchart (continued)

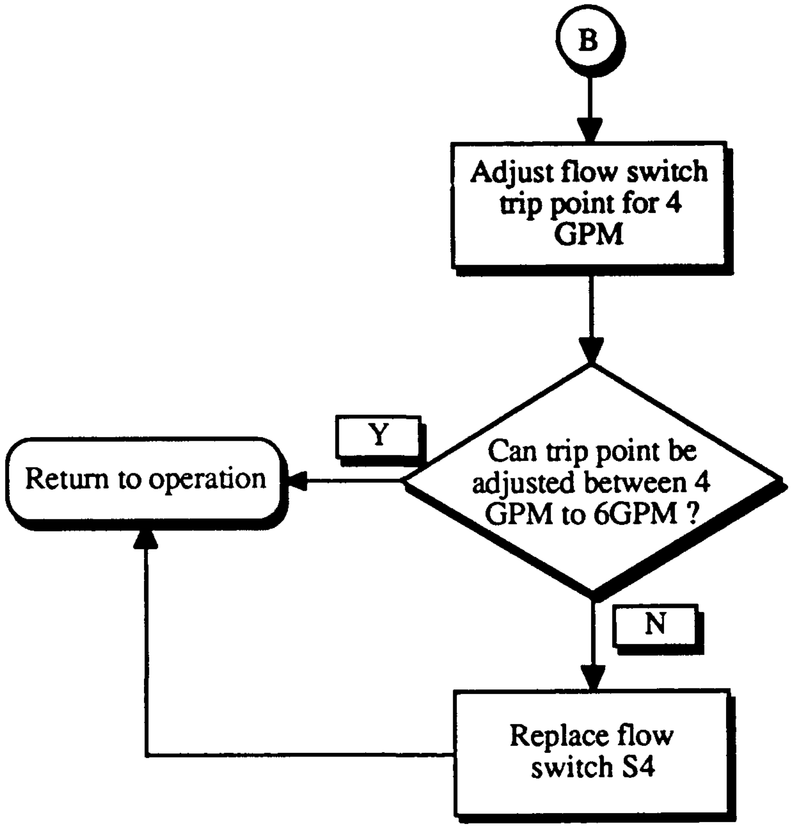

Figure A.11 Coolant (FC-77) Flow Fault Troubleshooting Flowchart (continued)

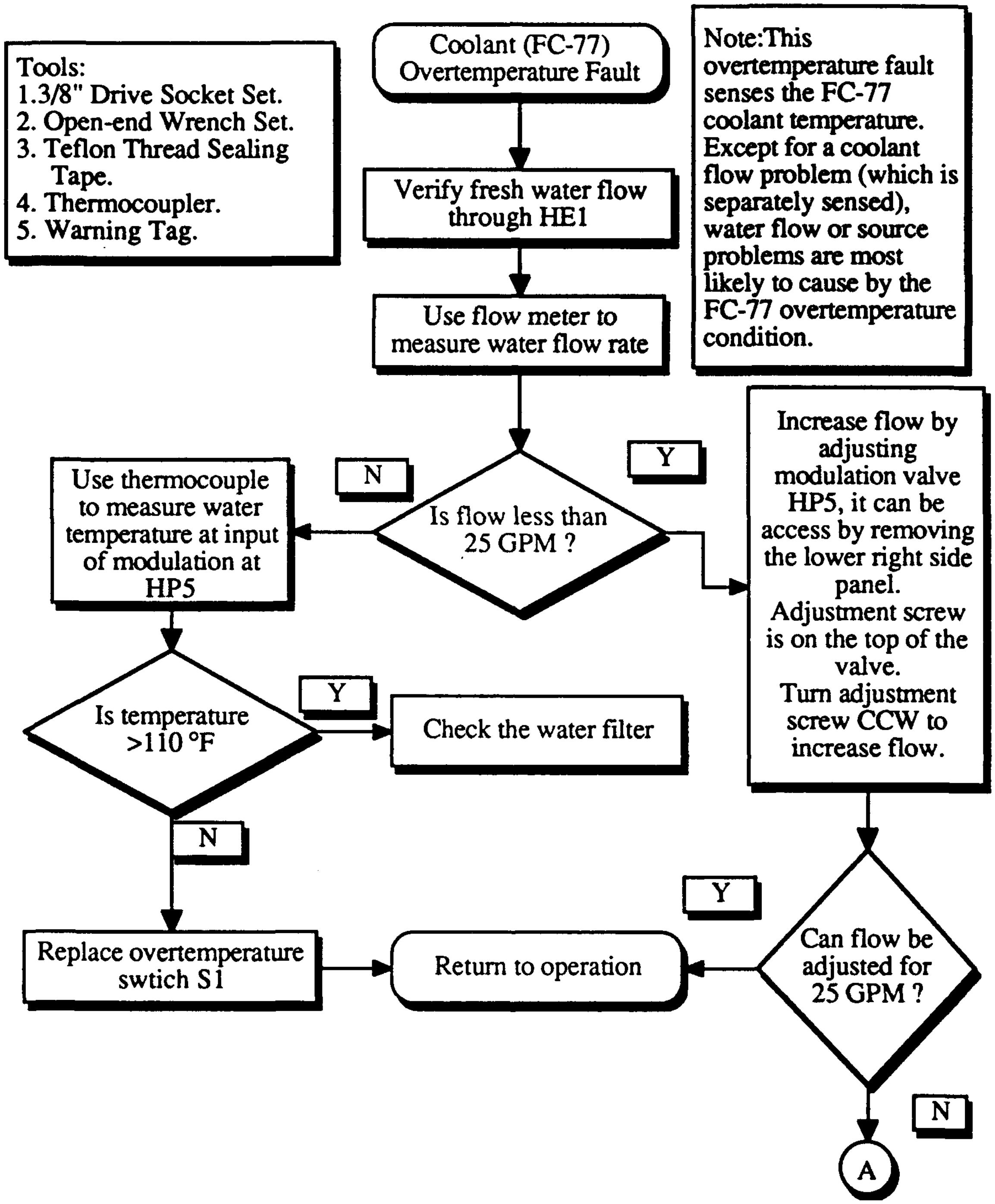

Figure B.12 Coolant Overtemperature Fault Troubleshooting Flowchart

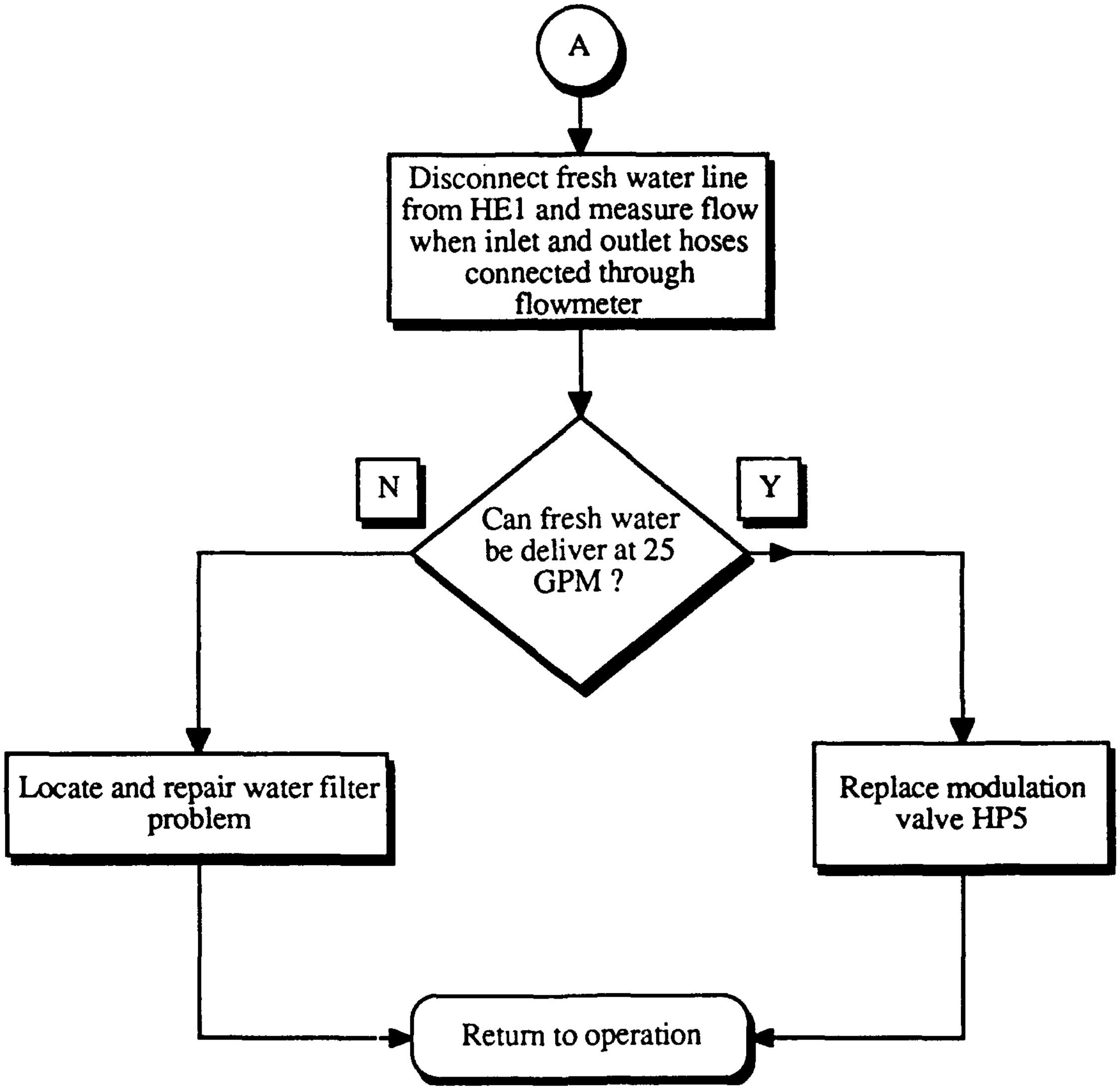

Figure B.12 Coolant Overtemperature Fault Troubleshooting Flowchart (continued)

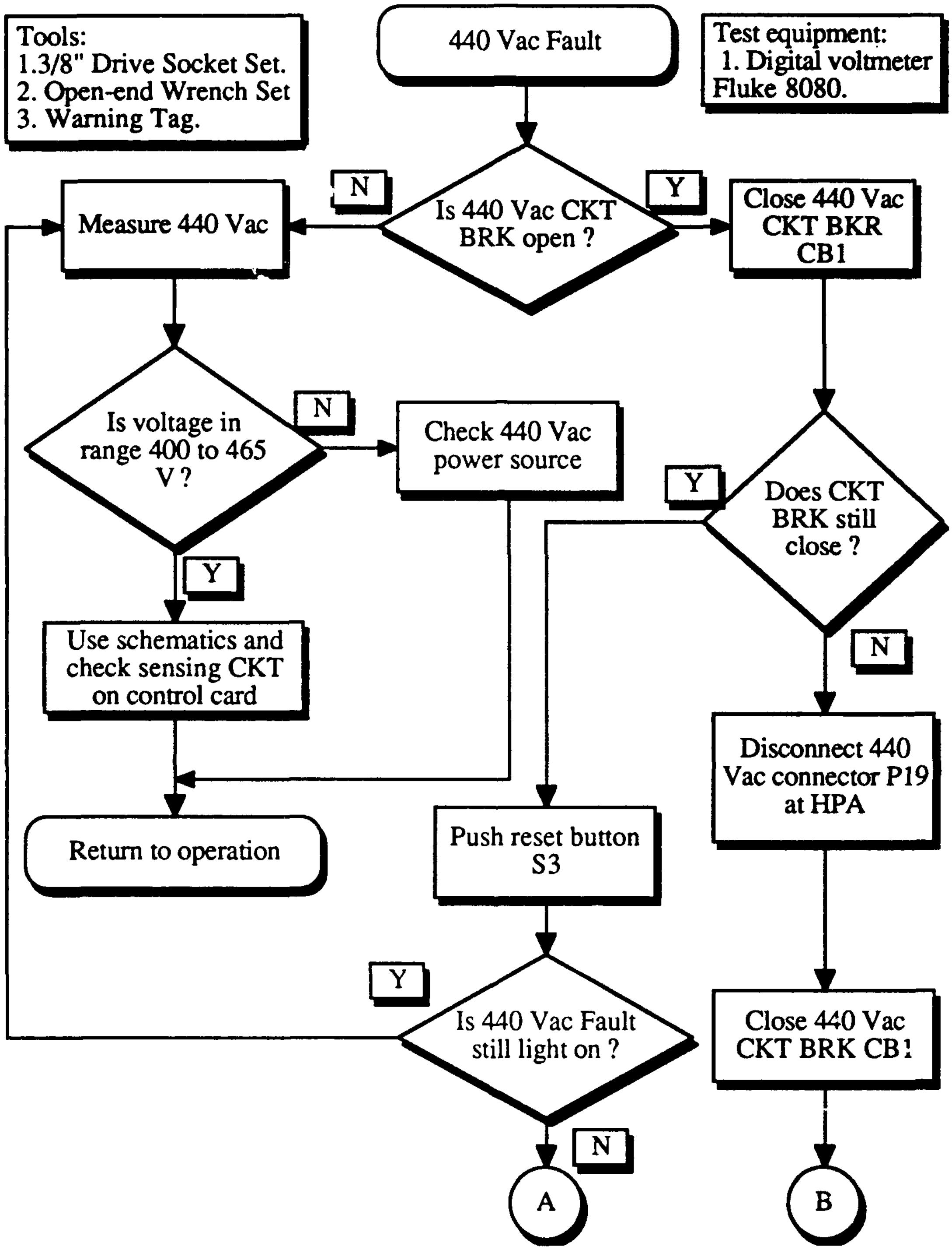

Figure B.13 440 Vac Fault Troubleshooting Flowchart

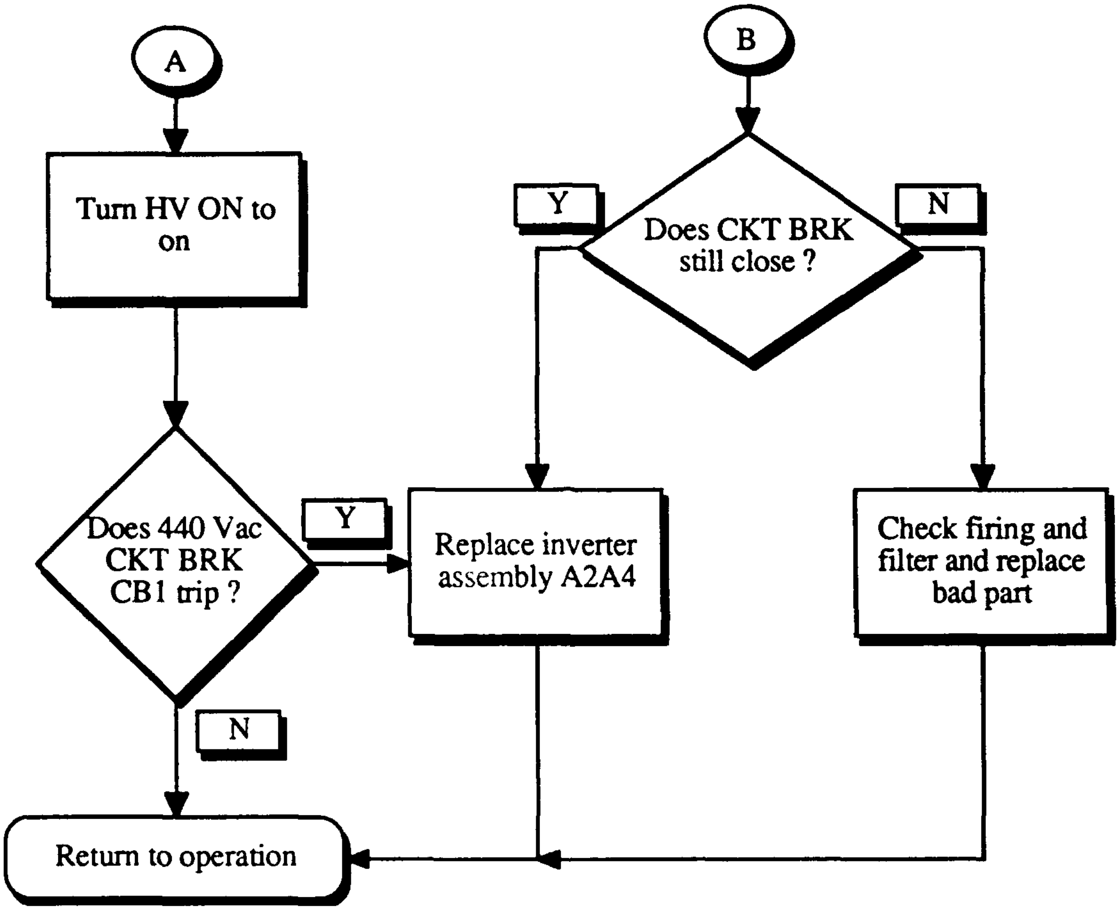

Figure B.13 440 Vac Fault Troubleshooting Flowchart (continued)

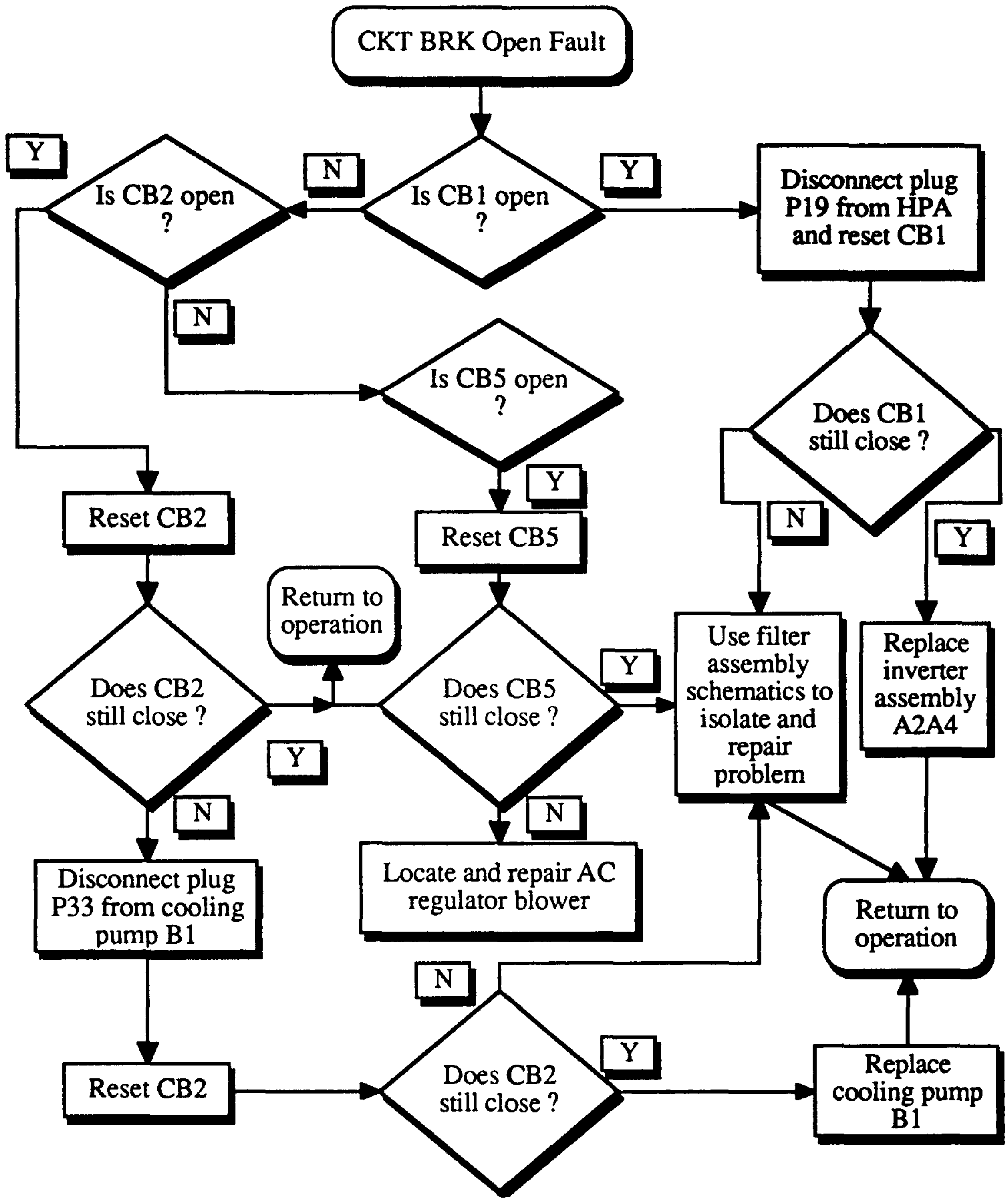

Figure B.14 Circuit Breaker Open Fault Troubleshooting Flowchart

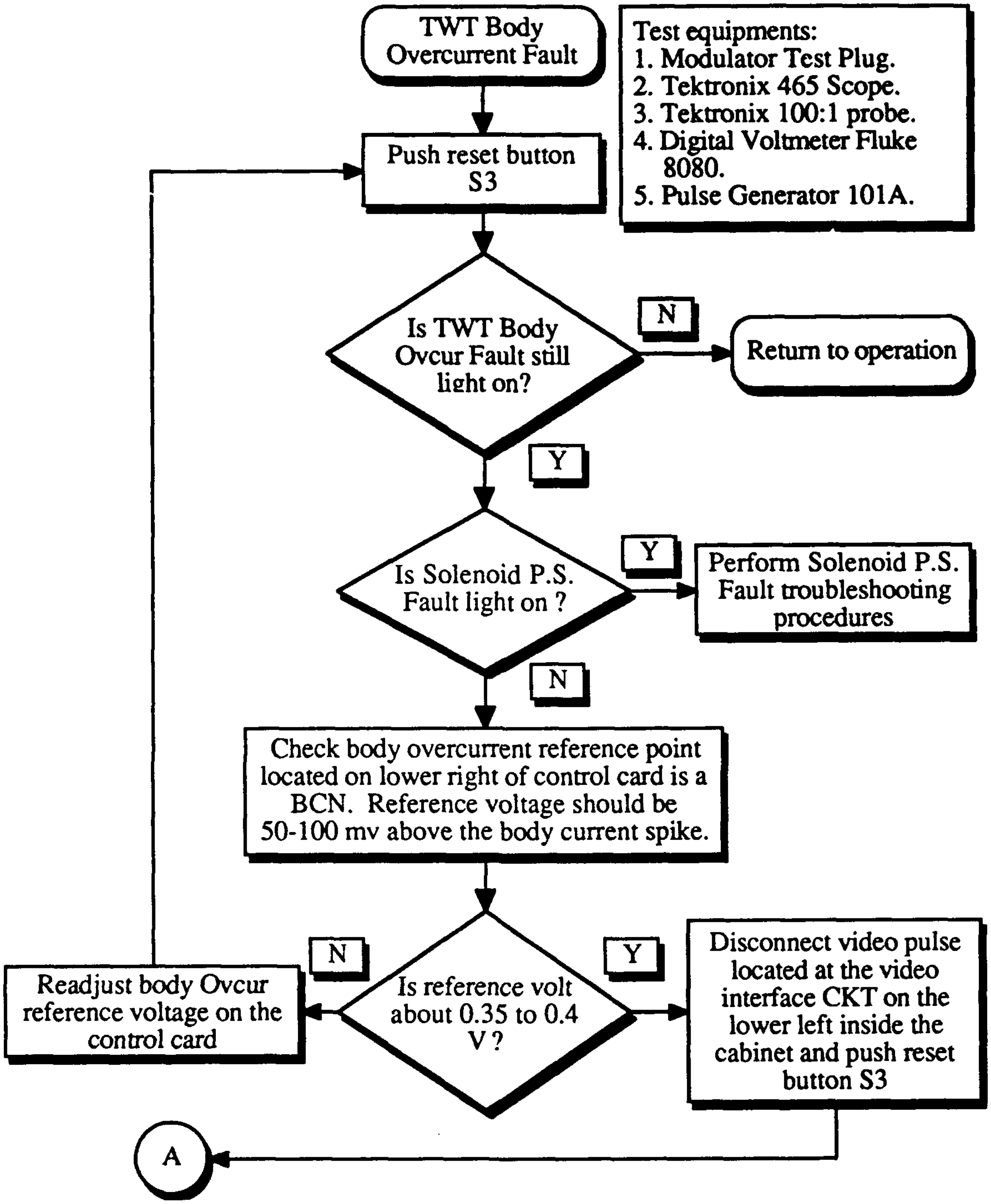

Figure B.15 Body Overcurrent Fault Troubleshooting Flowchart

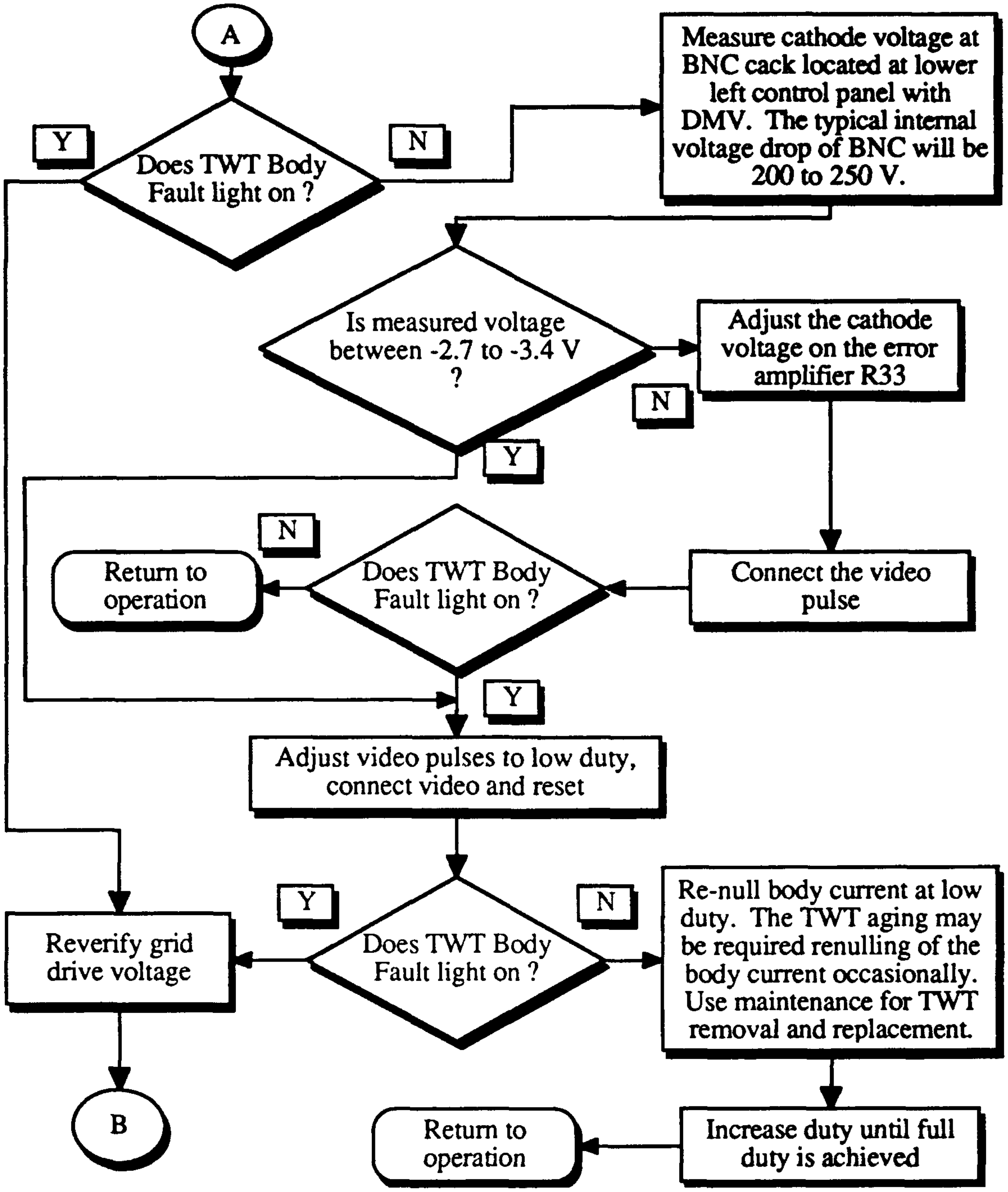

Figure B.15 Body Overcurrent Fault Troubleshooting Flowchart
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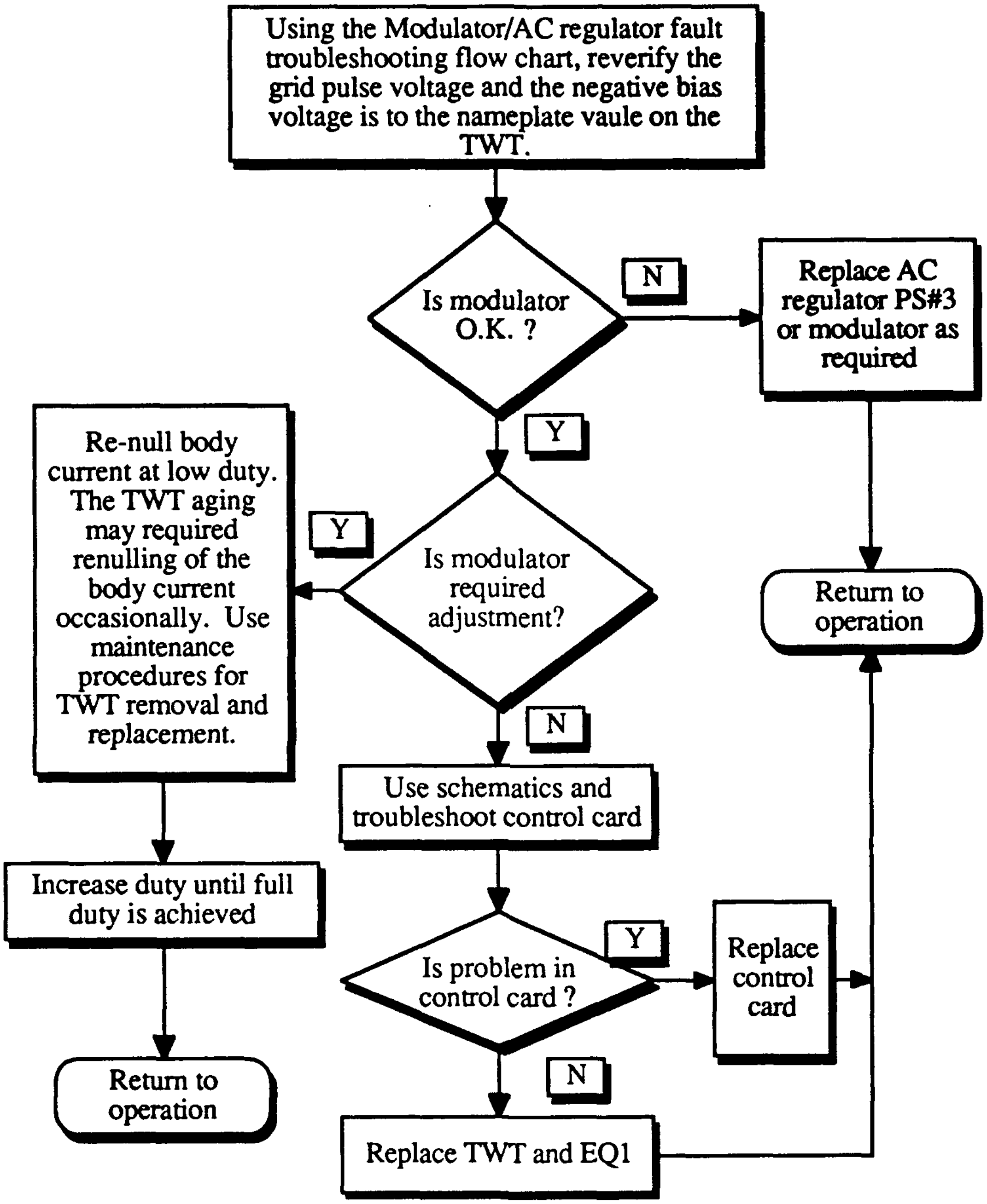

Figure B.15 Body Overcurrent Fault Troubleshooting Flowchart (continued)

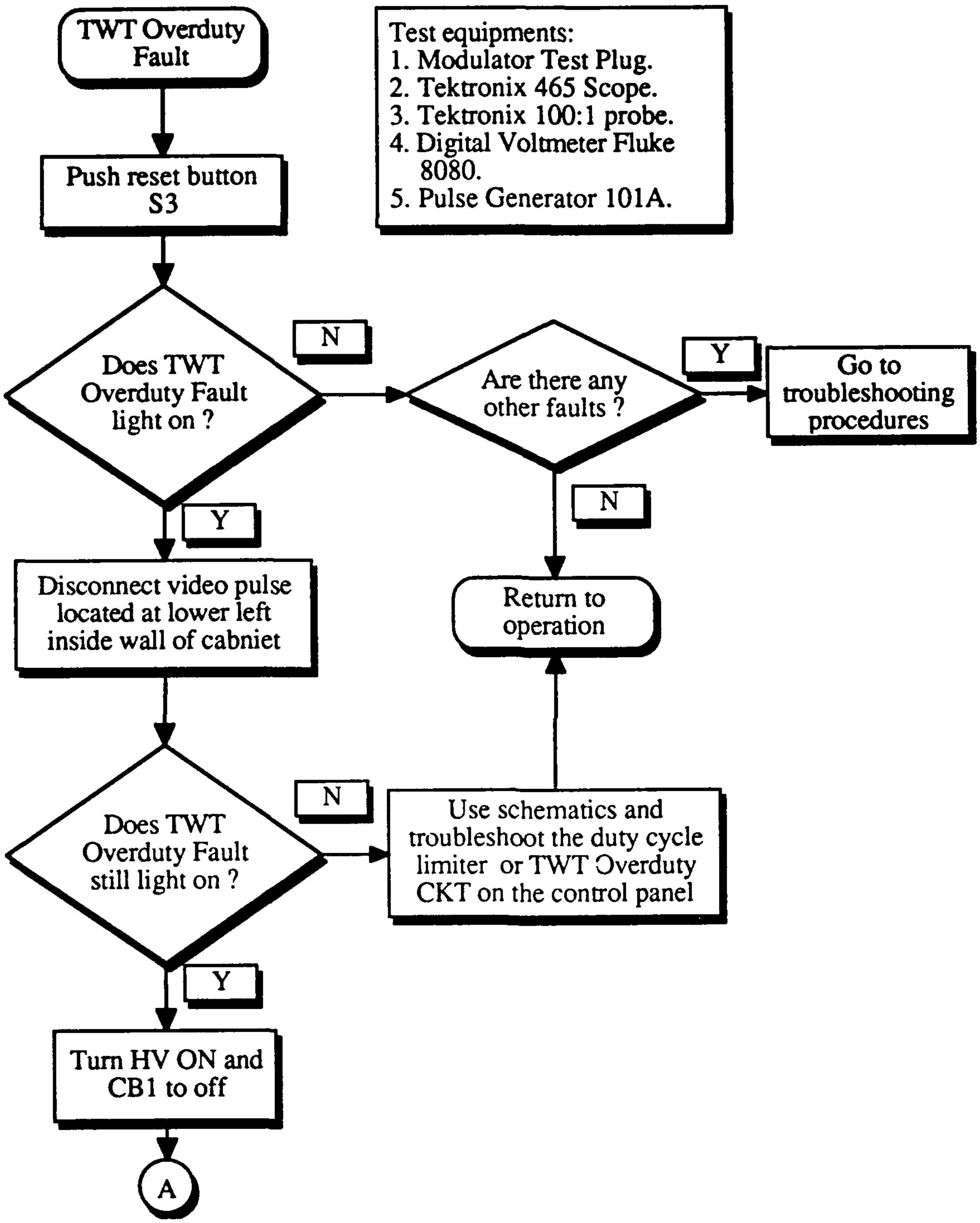

Figure B.16 TWT Overduty Fault Troubleshooting Flowchart

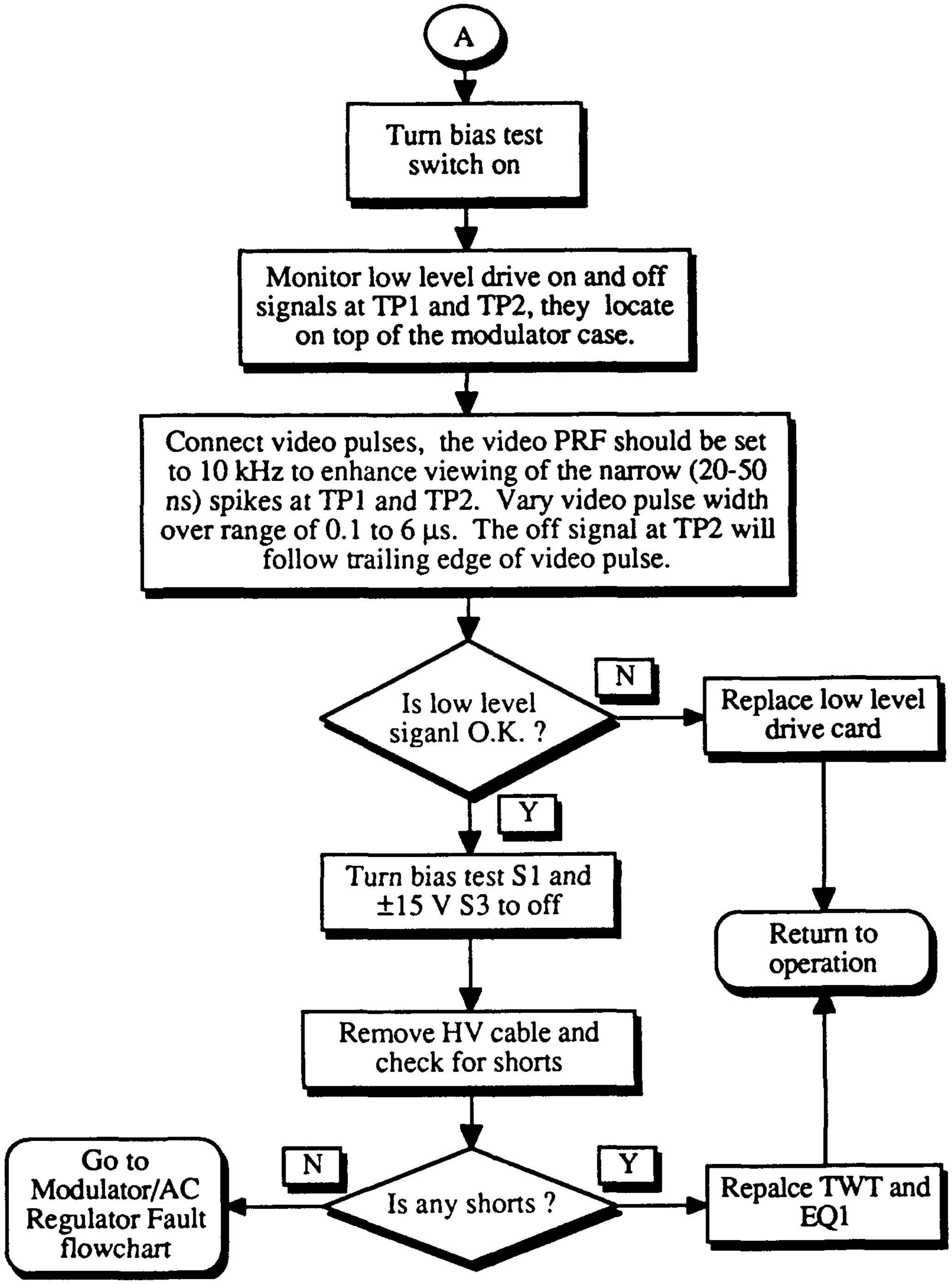

Figure B.16 TWT Overduty Fault Troubleshooting Flowchart (continued)

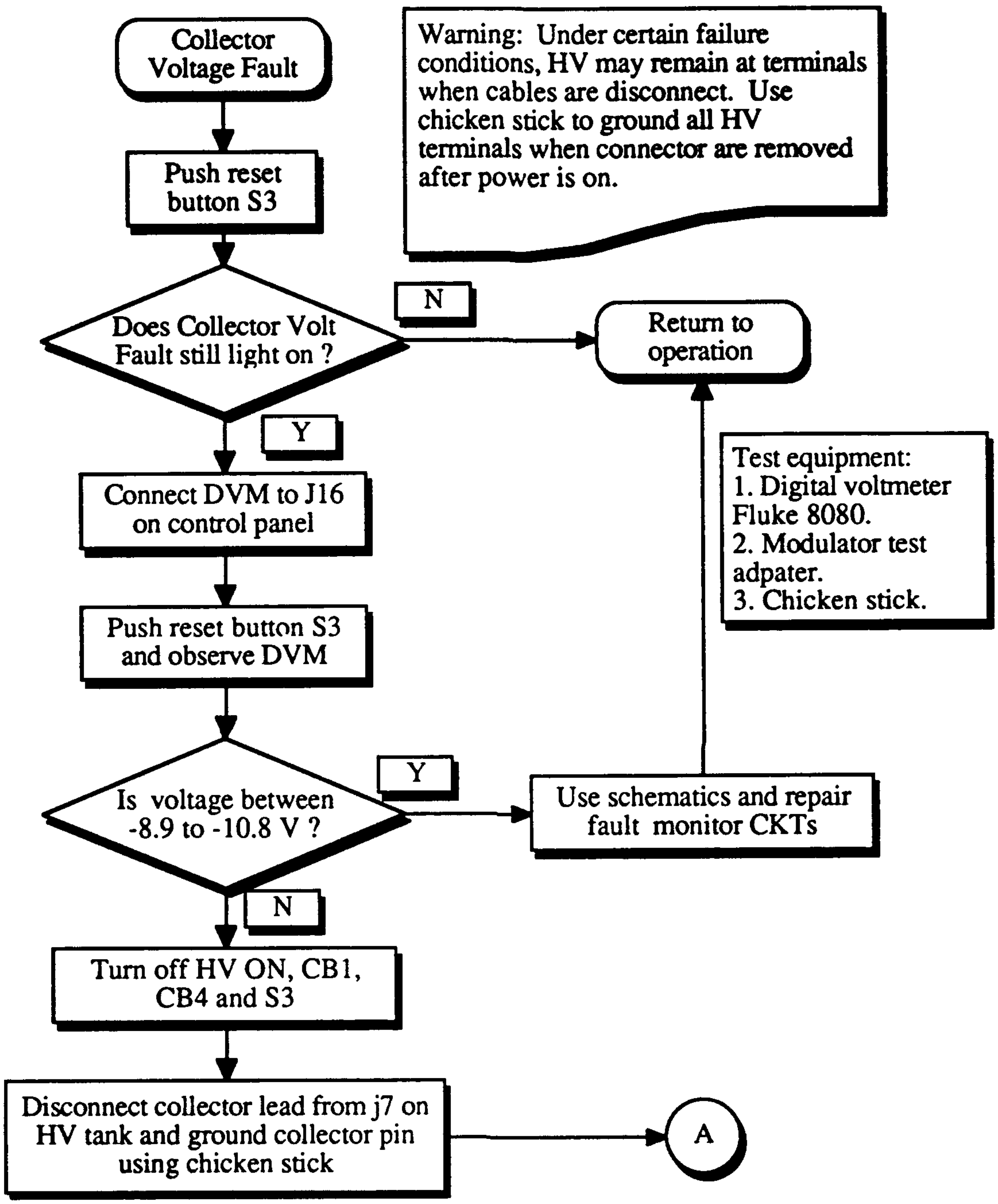

Figure B.17 Collector Voltage Fault Troubleshooting Flowchart

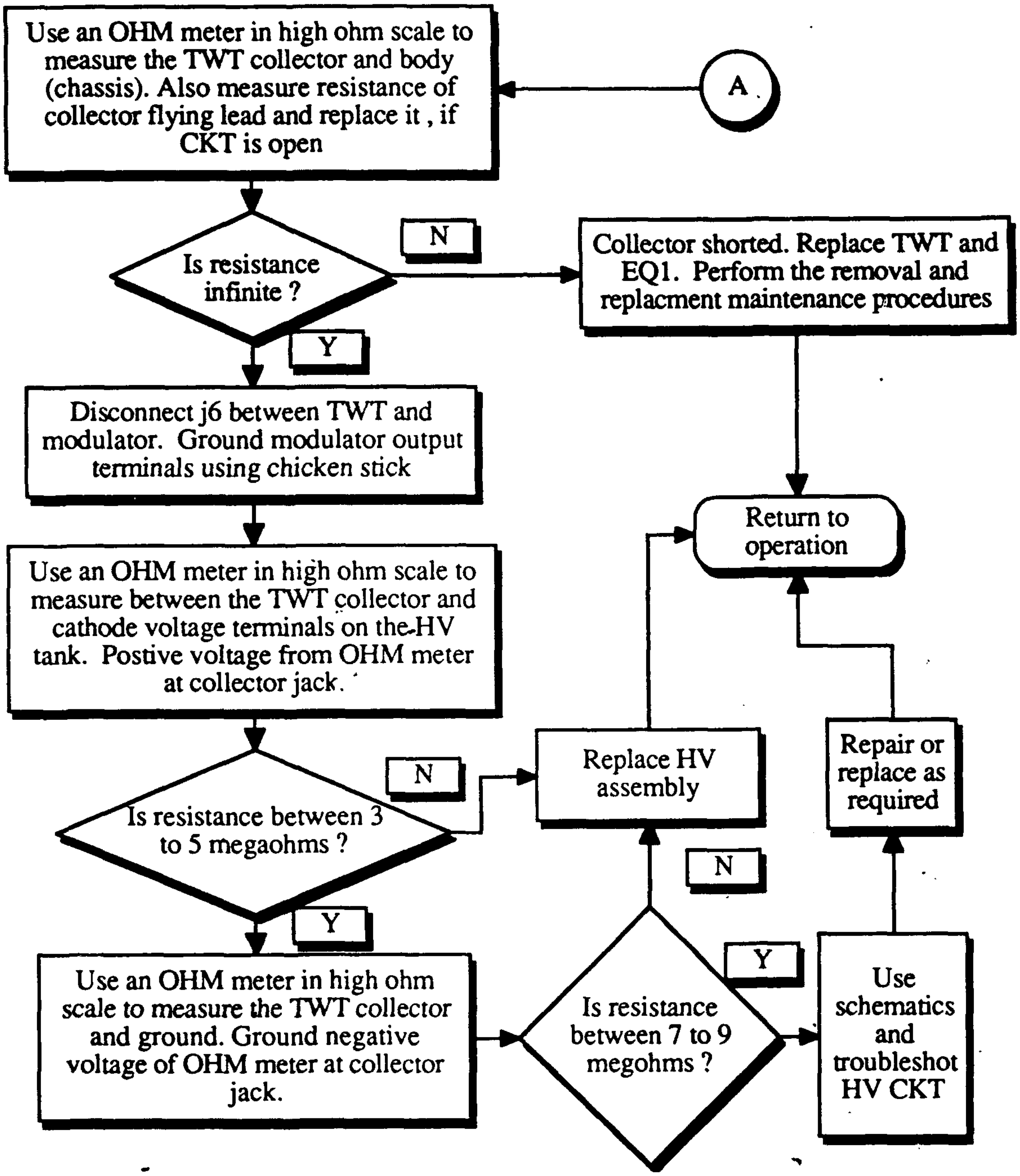

Figure B.17 Collector Voltage Fault Troubleshooting Flowchart

(continued)

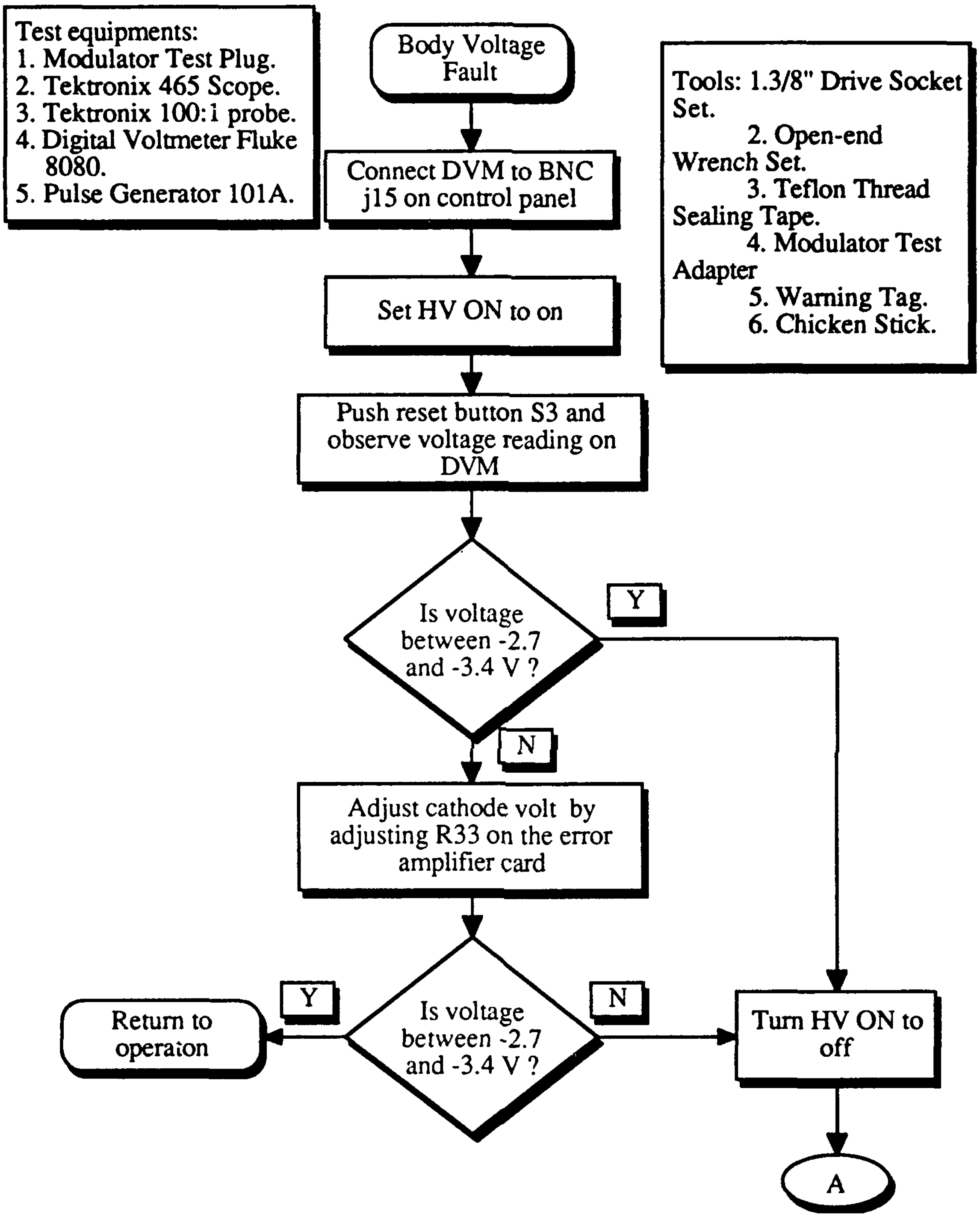

Figure B.18 Body Voltage Fault Troubleshooting Flowchart

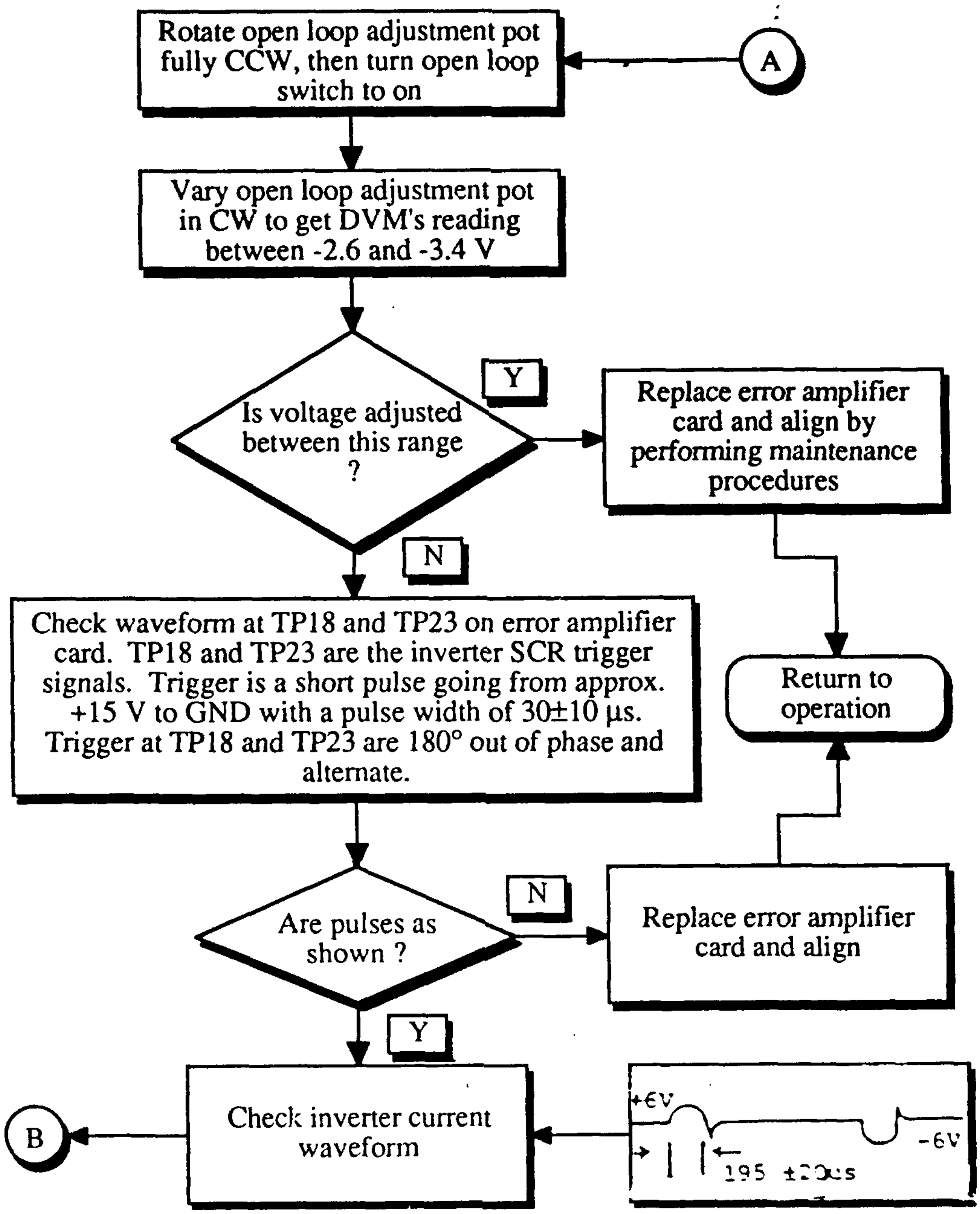

Figure B.18 Body Voltage Fault Troubleshooting Flowchart (continued)

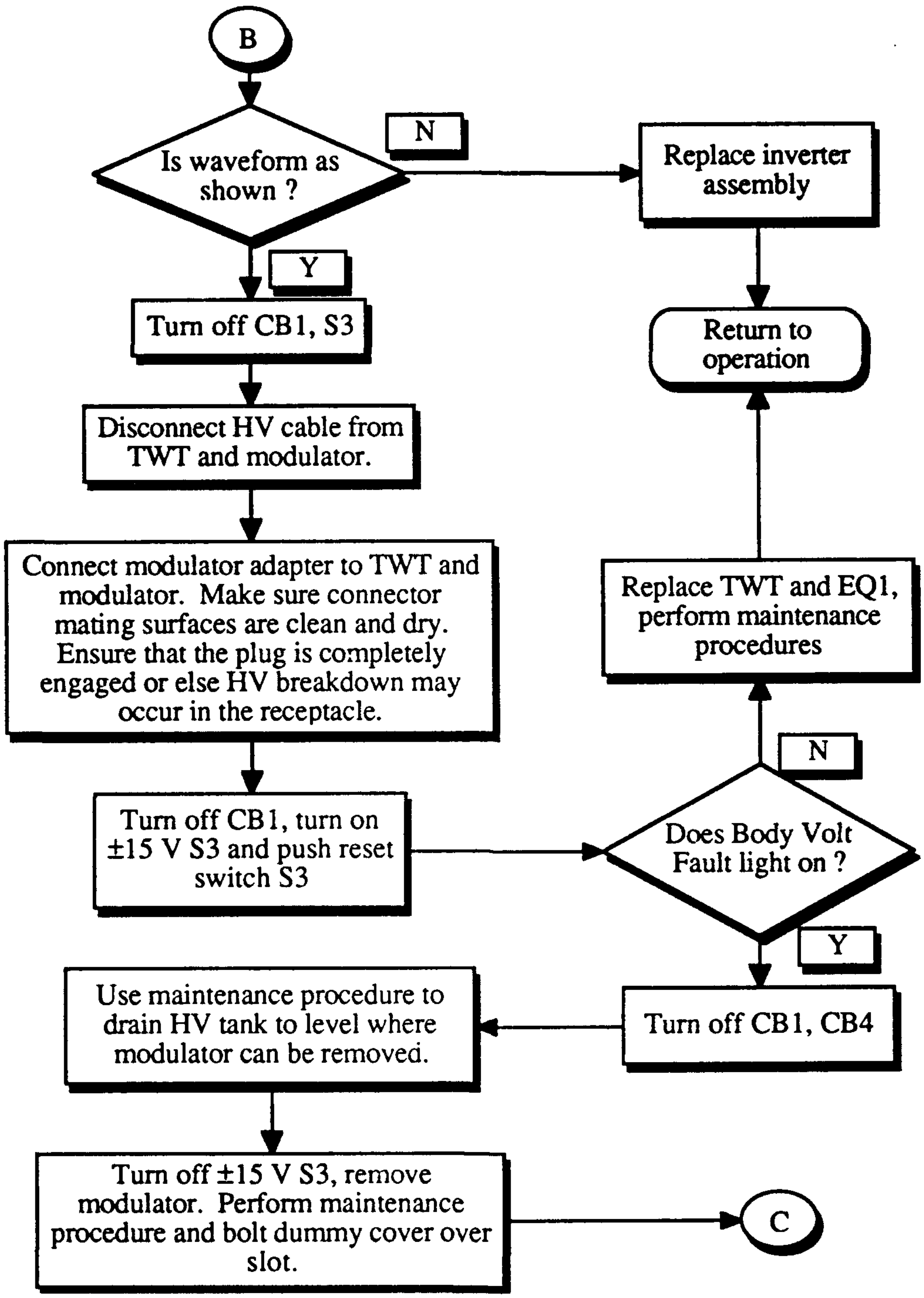

Figure B.18 Body Voltage Fault Troubleshooting Flowchart (continued)

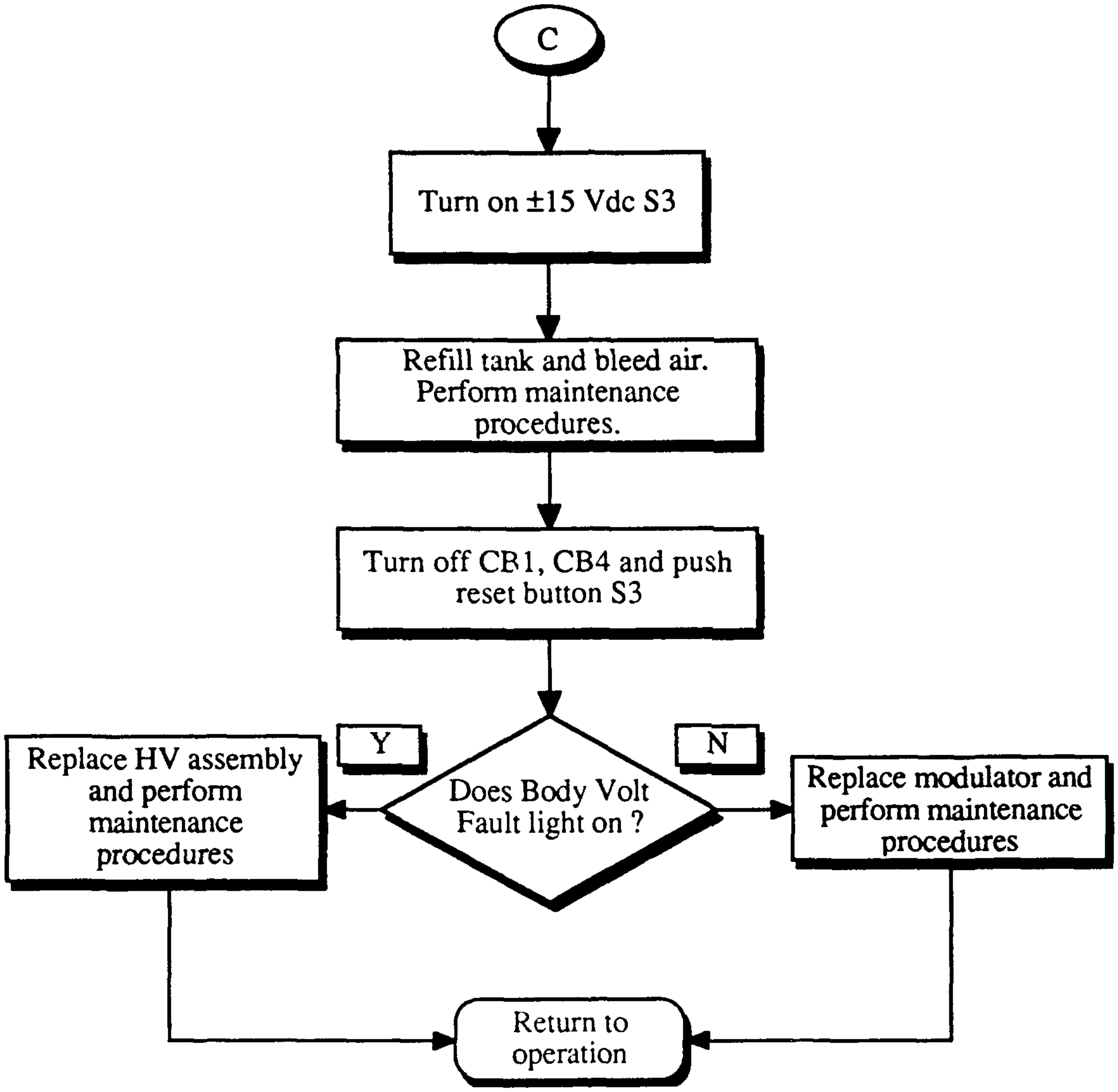

Figure B.18 Body Voltage Fault Troubleshooting Flowchart (continued)

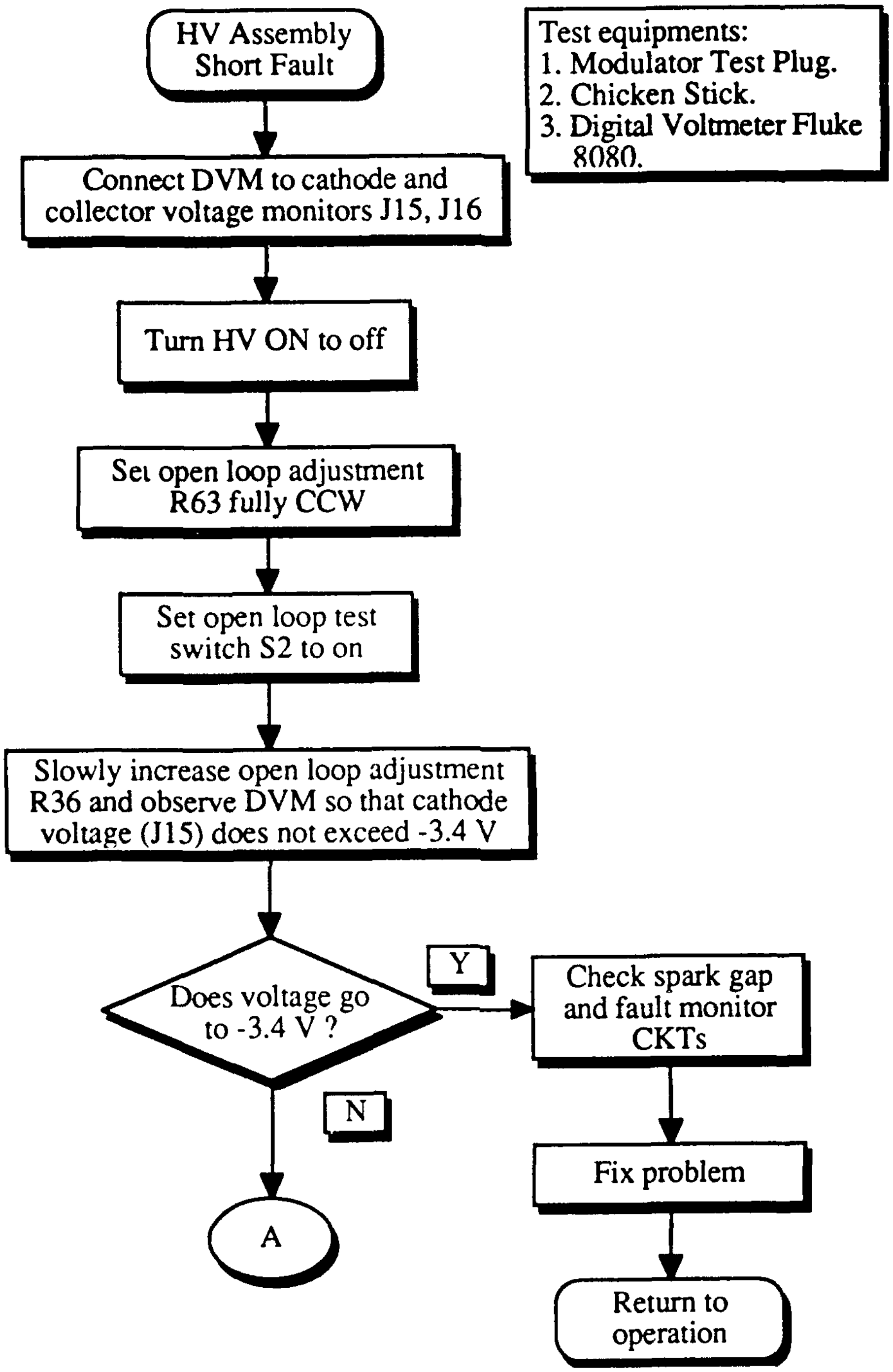

Figure B.19 High Voltage Assembly Short Fault Troubleshooting Flowchart

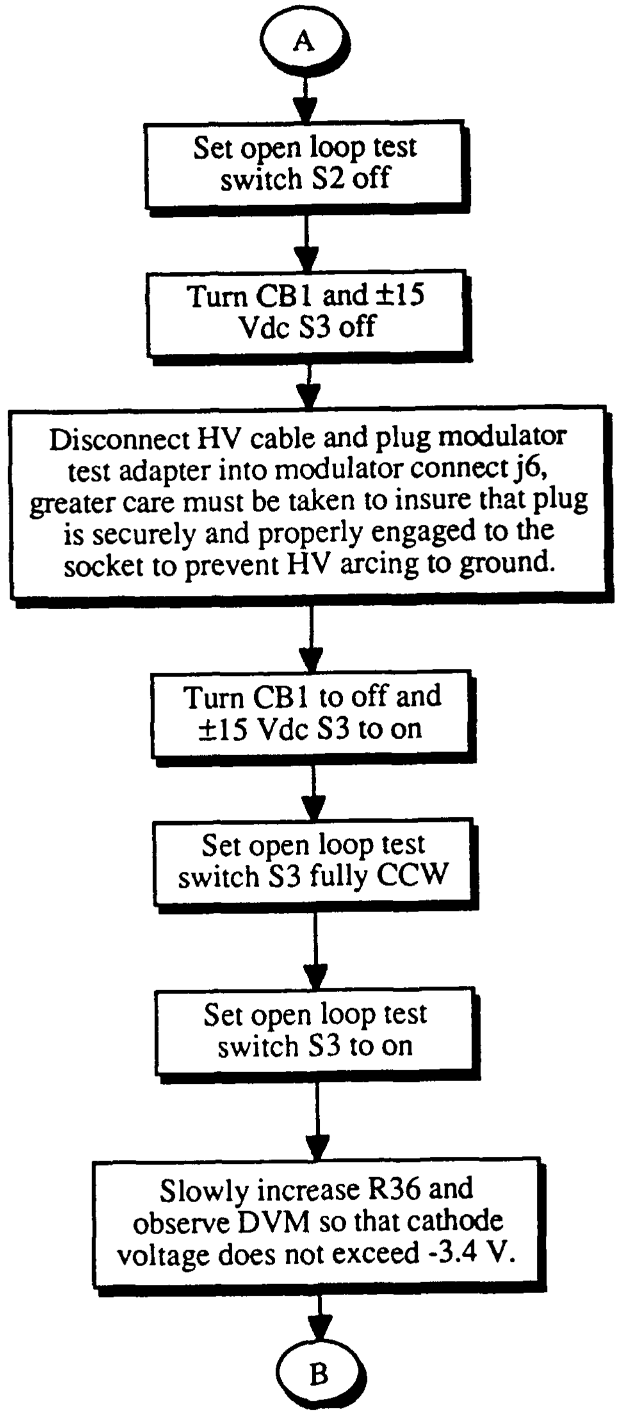

Figure B.19 High Voltage Assembly Short Troubleshooting Fault Flowchart (continued)

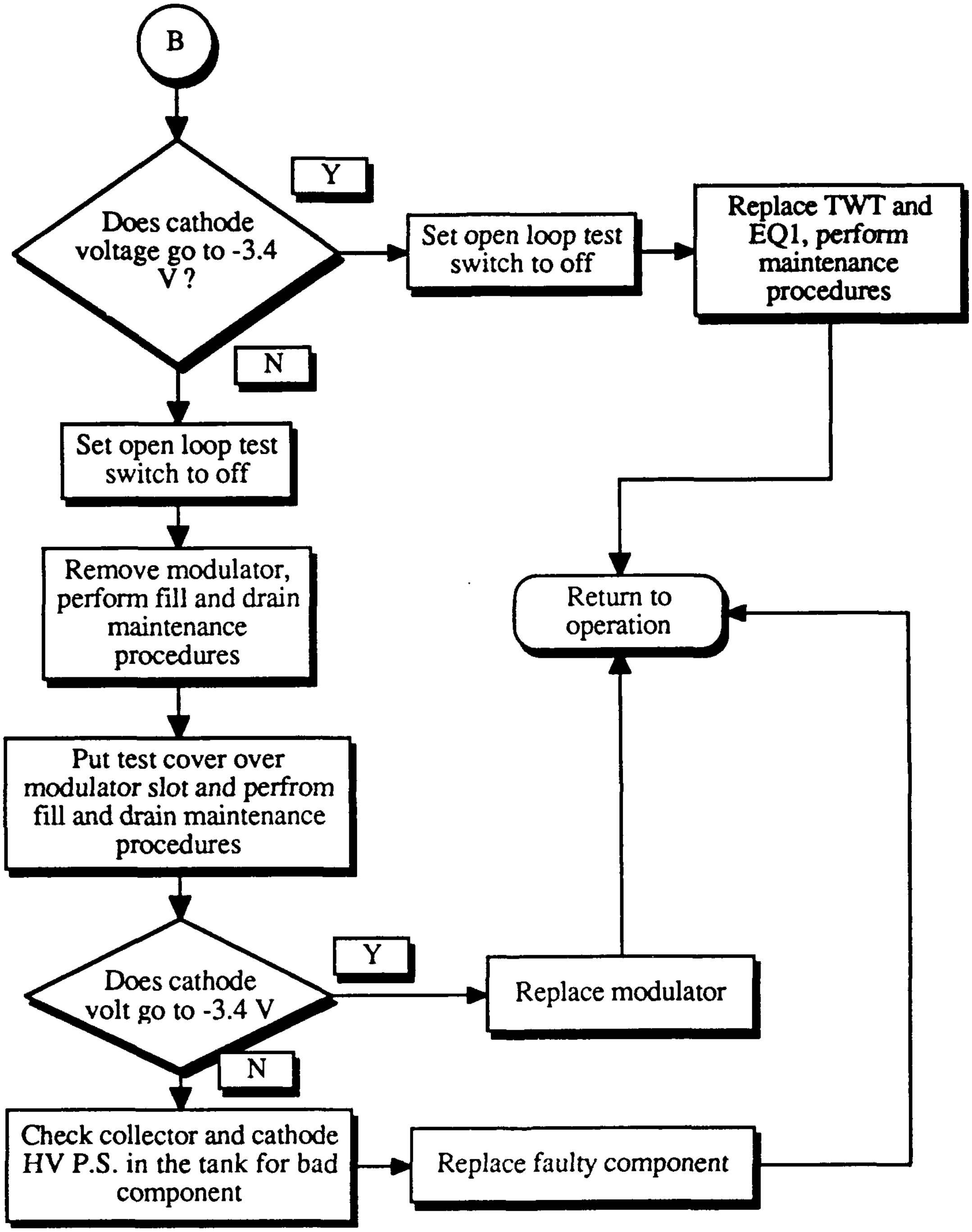

Figure B.19 High Voltage Assembly Short Troubleshooting Flowchart (continued)

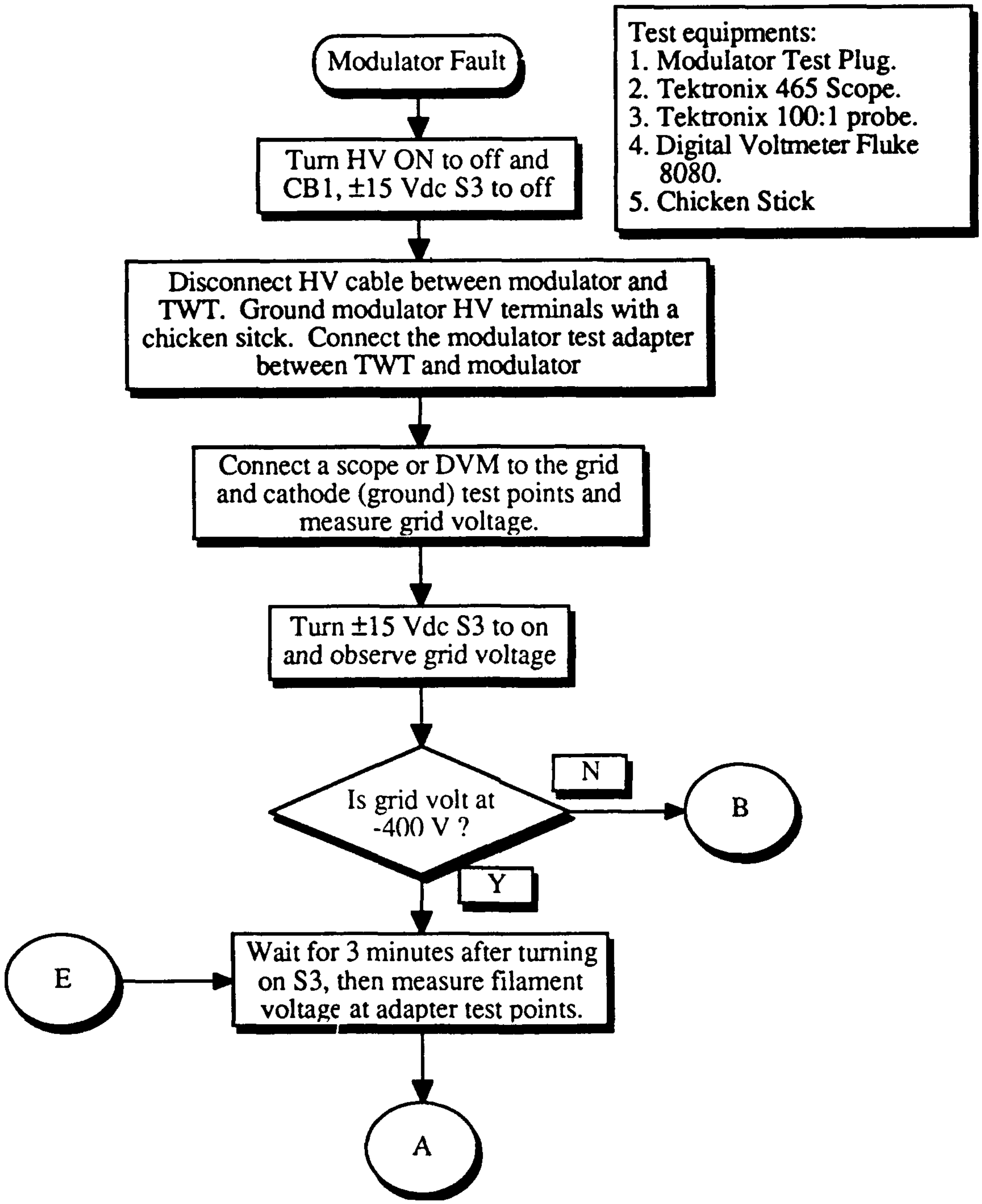

Figure B.20 Modulator Fault Troubleshooting Flowchart

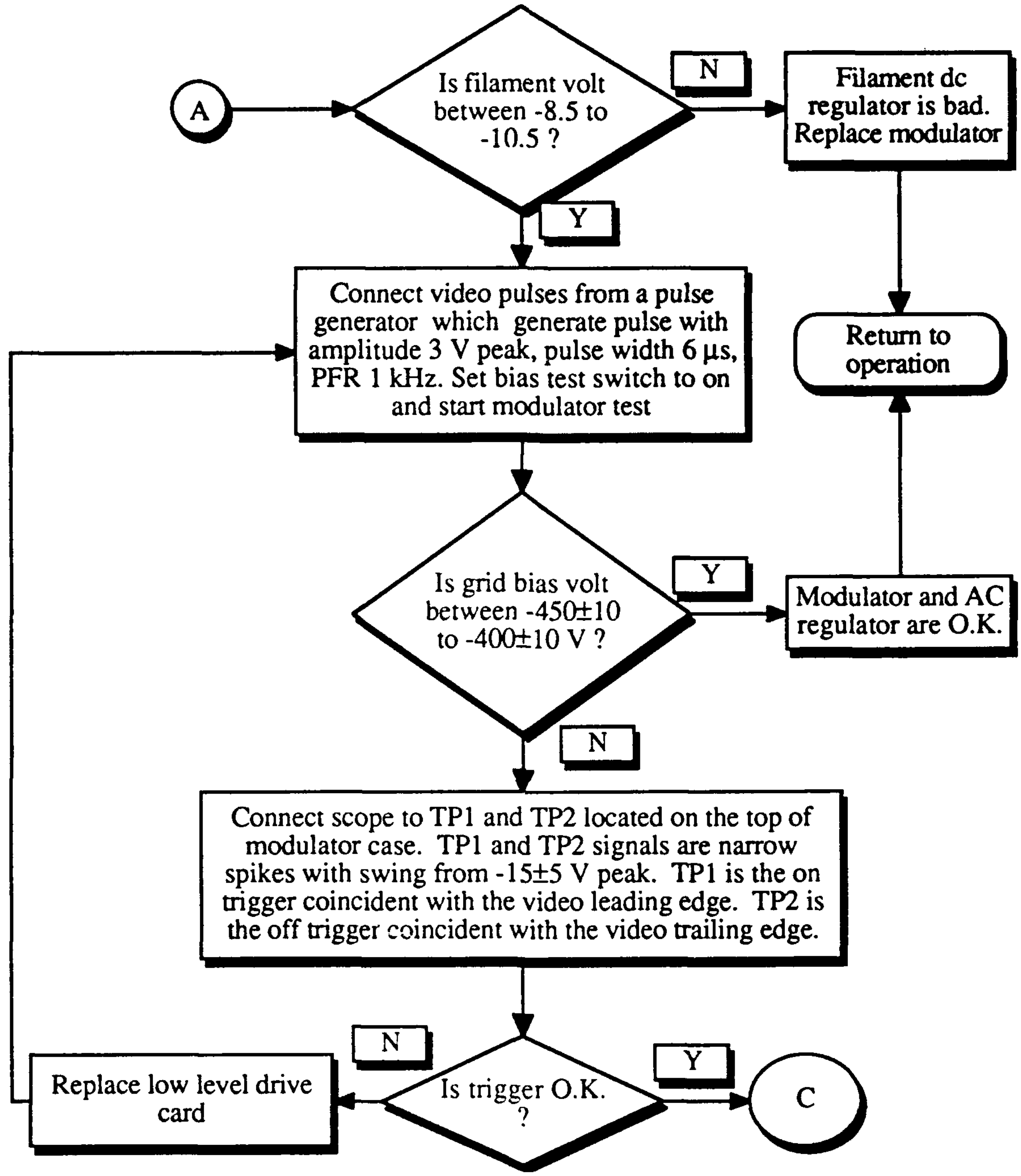

Figure B.20 Modulator Fault Troubleshooting Flowchart (continued)

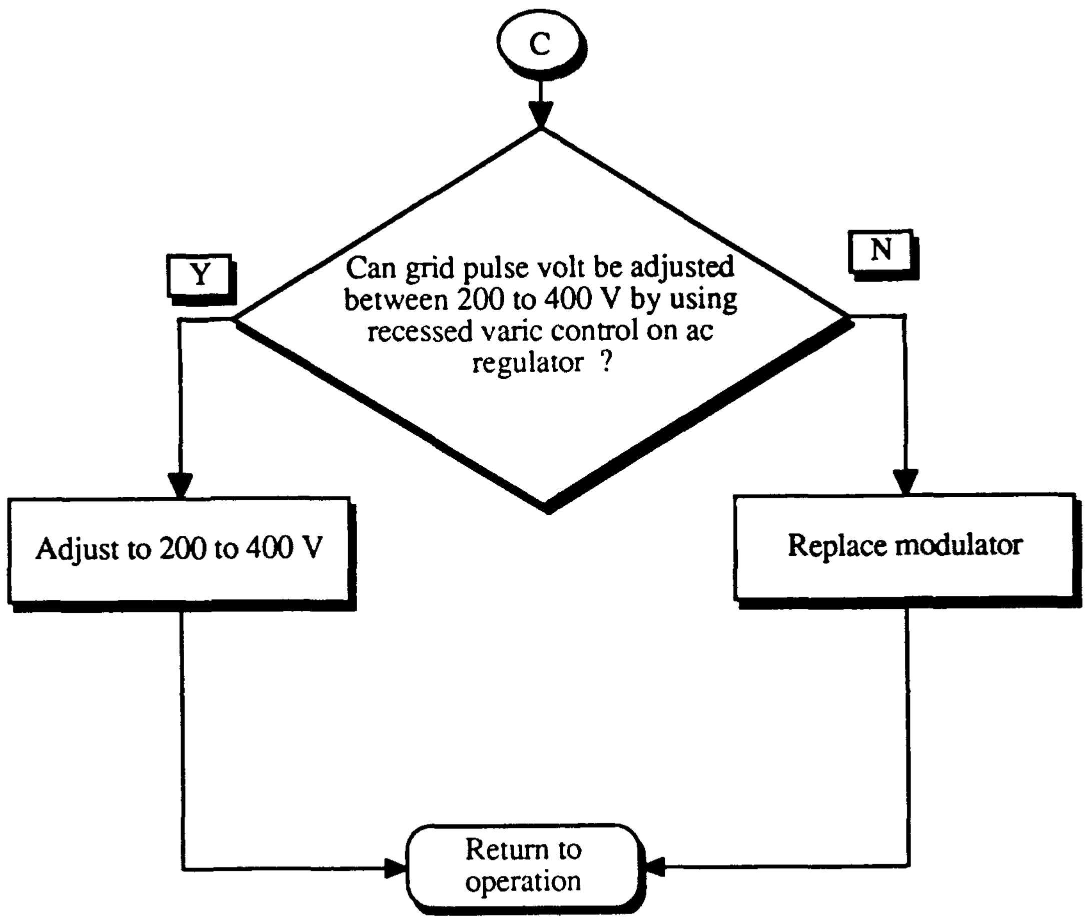

Figure B.20 Modulator Fault Troubleshooting Flowchart (continued)

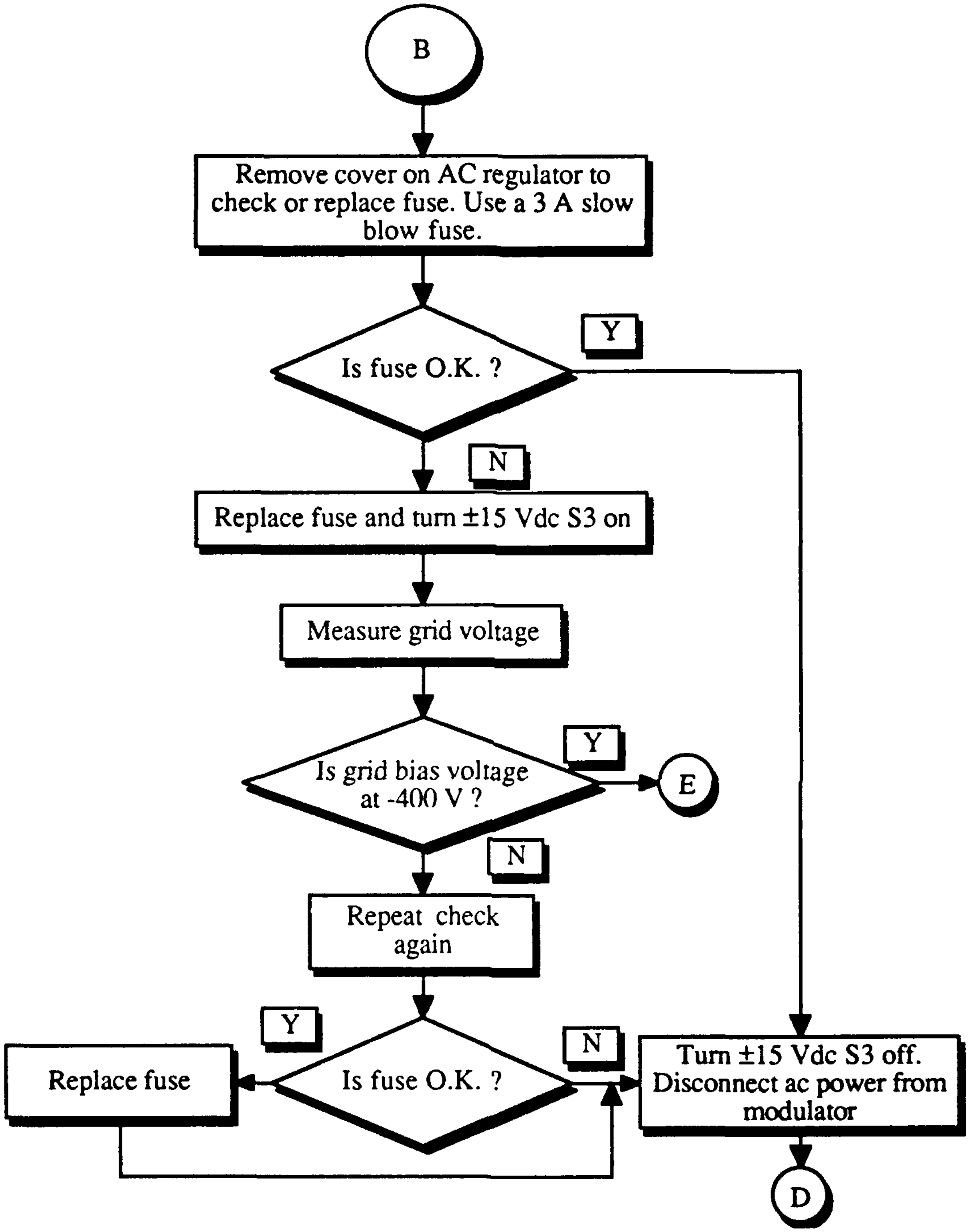

Figure B.20 Modulator Fault Troubleshooting Flowchart (continued)

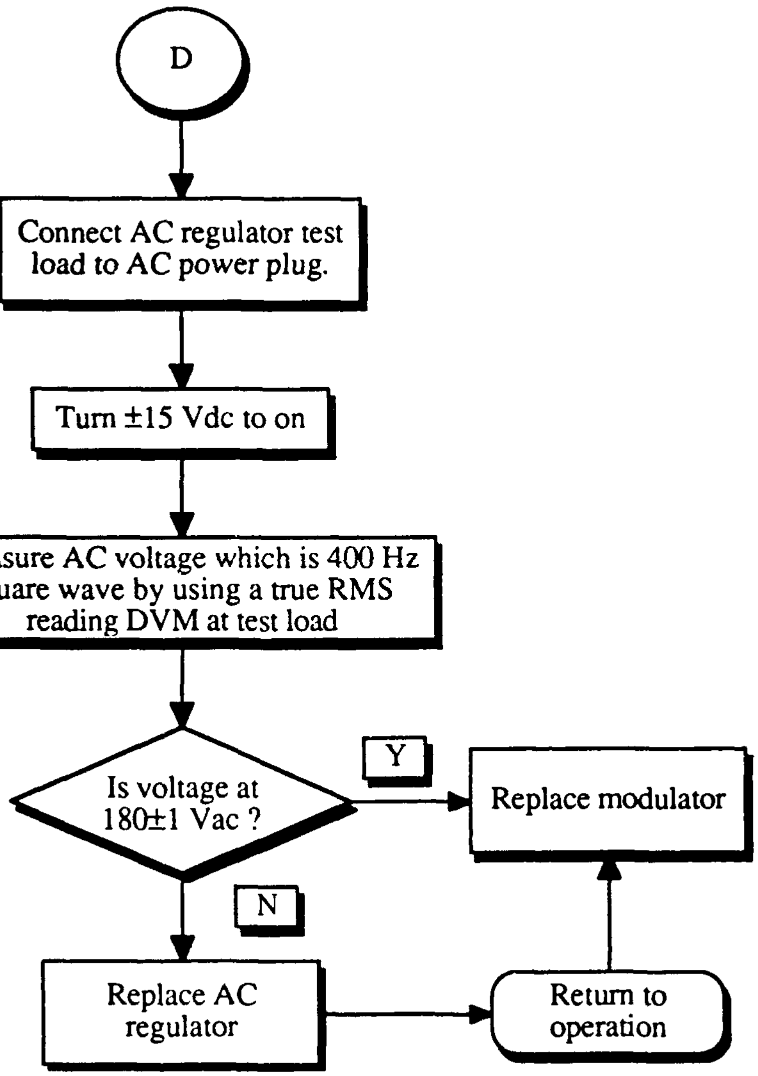

Figure B.20 Modulator Fault Troubleshooting Flowchart (continued)

APPENDIX C TWT SPECIFICATIONS TABLE

Item	Value	Unit
Cathode Voltage (Ek)	29.5	kV
Cathode Current (ik)	3.6	A
Collector Voltage (Ec)	-400	V
Filament Voltage (Ef)	-10.8	V
Solenoid Voltage (Egy)	260	V
Solenoid Current (Is1)	150	A
Solenoid Current (Is2)	150	A
Input Signal Level	29	dBm
FC-77 Flow Rate	4.5	GPM
RF Duty	0.004	

APPENDIX D HPA COMPONENT ABBREVIATIONS

Abbreviation	Component or Wiring
DC1	Direction Coupler
CP1	RF Detector Connector
AT1	Liquid Cooled Circulator
EQ1	Equalizer
V1	TWT
AT8	Liquid Cooled Circulator
DC2	Bi-direction Coupler
CP2	RF Detector Connector
CP3	RF Detector Connector
AT1	25 dB Attenuator
A2-A6-j6	Cathode-To-Body Voltage Cable
A2-j7	Collector-To-Body Voltage Cable
A9	RF Monitor Circuit
A9-j3-2	High VSWR Monitor wiring
A4	Ion Pump Power Supply
A4-j3-18	Ion P.S Undervoltage wiring
A4-j3-19	Ion P.S Overcurrent wiring
j2	Solenoid P.S. power line

Table D.1 RF Amplifier Abbreviations (Figure 3)

Abbreviation	Component or wiring
A2	High Voltage Supply Tank
A2-j1	Error Amplifier And Inverter Driver Card
A2-j1->P15,8,25	Inverter INHIB, HV sense and Open Loop Trig signals output line
A2-j3-25->P3,8, 32	Body Voltage, HV Assembly Short and Crowbar Trig sensing signals output line
A2-j6	Inverter Current sensing signal output line
A6	Modulator
A6-j5	Low Level Modulator Drive Card
A6-j5-P13	Modulator Video signal input line
A6-j5-p23->P5, 6,3	Output line of the sensing signals include collector's and cathode's current and voltage signals
A6-j4-p20->P16	Crowbar power line (115 Vac)
PS#3	48 Vdc Regulator
PS#3->A7-j1-P52-8,7,A8-j1-P54-8,7,A9-j1-P56-8,7	48 Vdc power lines
A7-j1-P52-5,9,A8-j1-P54-5,9,A9-j1-P56-5,9->A6-j2-P16	Sensing voltage output line
A7-j1-P53-4,5,A8-j1-P55-4,5,A9-j1-P57-4,5->A6-j2-P26	Output voltage lines of Regulators
A7-j1-P53-1,2,A8-j1-P55-1,2,A9-j1-P57-1,2->j7-1,3,5	Voltage monitor lines
B1j1->P16	440 Vac 400 Hz 3-Phase power line
A5->A2-P19	600 Vdc power line

Table D.2 High Power Supply Unit And Modulator Unit Abbreviations (Figure 4)

Abbreviation	Component or Wiring
A10	Power Distrubition Unit
CB1	400 Vac 400 Hz 3-Phase switch
CB2	Cooling Pump Control switch
CB3	115 Vac 60 Hz single phase switch
A10-A1,B1,C1 -> A5-CR-8,9,10	400 Vac 400 Hz 3-Phase power line
A10-j3-p16-1,2,3-> B1-j1	400 Vac 400 Hz 3-Phase power line
A10-j3-p16-30,31-> A4-j1-P35-A,B	115 Vac 60 Hz Single Phase power line
A10-P16-j3-5,6,27,28,34,35,36->PS #1,PS#2,A6-j2-P26-14,15,A6-j4-P20-1,2	115 V 4u0 Hz Single Phase power line
A6-P26-16,17->PS#3	115 V 400 Hz Single Phase power line
PS#3->A7,A8,A9-7,8	48 Vdc Power Line
PS-1-4,PS2-6->A10-j2-5,6,7,8,12,13	±15 Vdc power line
A10-P15-j4-25,26,27,28,29,30,33,36,37,38,39,40,43,44,47,55,56->A3-j2-P2,A6-j1,A2-j1,A2-j3-P25,A9-j3, TTL,j7-8	±15 Vdc power line

Table D.3 Power Distribution Unit (Figure 7,8)

Abbreviation	Component or Wiring
B1	Cooling Pump
HP2	Resevior Valve
HP3	Auxiliary Valve
HP4	Vent Valve
HP5	Cooling Water Modulation Valve
HP6	Filter And Drier
HP8	Automatic Vent Valve
HP9	Moisture separator
HP10	Drain Vlave
HP11	Check Valve
HP12	Air Bleed Valve
HP13	Air Bleed Valve
HP14	W/G Air Pressure
HP19	Water Inlet Connection
HP20	Water Outlet Connection

Table D.4 Cooling Unit Abbreviations (Figure 9)

Abbreviation	Component or Wiring
QD1	Quick Disconnect
QD2	Quick Disconnect
HE1	Heat Exchanger
TV1	Throttle Valve
BV1	Bypass Valve
S1	Coolant Overtemperature Swtich
S2	Liquid Level Switch
S4	Flow Interlock Switch
S5	Flow Interlock Switch
SG1	Sight Class

Table D.4 Cooling Unit Abbreviation (continued)

LIST OF REFERENCES

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2. *Solid State Modulator*, Hughes Aircraft Company Technical Report FR 83-14-1210, April 1983.

3. O.P. Gandhi, *Microwave Engineering and Application,* Pergamon Press, New York, 1981.

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5. J.L. Eaves and E.K. Reedy, *Principles of Modern Radar*, Van Nostrand Reinhold, New York 1987.

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